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AN ECONOMETRIC STUDY OF ENERGY AND RESOURCE USE IN CANADIAN MANUFACTURING INDUSTRIES

by

©

Mohammad Abu Taher

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled AN ECONOMETRIC STUDY OF ENERGY AND RESOURCE USE IN CANADIAN MANUFACTURING INDUSTRIES submitted by Mohammad Abu Taher in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY.

Dedicated to my parents.

ABSTRACT

The objective of this dissertation was to investigate the role of energy and natural resources in the Canadian manufacturing sector. The dissertation examines factor demands and substitution possibilities, productivity performance, and the effects of energy and resource price increases on factor demands and unit costs of production for 20 manufacturing industries and total manufacturing. In contrast to the previous studies which usually specify a four input model (KLEM), incorporating capital, labour, energy and materials this study specifies a five input model (KLERN), incorporating renewable and non-renewable resources (R and N respectively) in addition to KLE. This was done because renewable and non-renewable resources are often significant inputs into Canadian manufacturing and, like energy, have experienced considerable price variation over the 1961-1976 study period. Also it may be necessary to treat these factors as separate production inputs in order both to obtain a good representation of the manufacturing production technology and to provide information useful to resource management policy.

The translog cost function was used as the framework of analysis and a system of share equations derived from it were estimated for total manufacturing and twenty two-digit industries. Annual national data for the 1961-1976 period were used. Data construction was a major task and the methodology of its construction are reported.

Appropriate constraints for testing of homotheticity (the production structure) of the cost function and the separability of inputs and groups of inputs were developed and empirically implemented. Likelihood ratio, Wald and F-tests were applied as necessary. The Canadian manufacturing industries are mainly characterized by a non-homothetic production technology. In general, labour, capital and energy are not independent (separable) of renewable and non-renewable resources. Factor price elasticities differ considerably across industries. It is noted, however, that those for renewable and non-renewable resources in total manufacturing are particularly low. Usually renewable resources substitute for energy but not for other non-renewable resources. Capital and energy are not uniformly complements but labour and energy are always substitutable.

Problems in determining parametric productivity estimates enabling the separation of scale and technical change contributing to total factor productivity were identified and overcome. Parametric productivity estimates are smaller than conventionally determined total factor productivity measures. Total factor productivity growth varies considerably and that may be attributed to a variety of factors. With the exception of some resource based industries, productivity rates decline after 1973.

The effects of energy, renewable and non-renewable resource price increases (20 and 50 percent) on input demand

and unit costs of production were simulated and found to vary widely across industries. The simulated impacts of energy price increases are similar to those of other Canadian studies but the effects on labour and capital are smaller which suggests greater adaptability in Canadian manufacturing than previously indicated. The effects of energy price increases on average cost of production are much less than the effects of renewable and non-renewable resource price increases of the same magnitude. This result and the nonseparability of the production technology indicate an advantage to explicitly integrating natural resource inputs in studies of Canadian manufacturing production.

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Chapter 1. Introduction

The economic development of Canada has been based on the exploitation of natural resources, both renewable and non-renewable. These resources, in raw or semi-processed form, are used as commodities of foreign trade as well as inputs for manufacturing production for the domestic and export markets. In the words of Dwivedi (1980),

> "The history of Canadian economic development has been dominated by trade in natural resources. Unlike other highly industrial nations, industrialization of Canada has been based on the fortuitous discovery of minerals, natural gas, petroleum, and on the exploitation of waterways for hydroelectricity, inland and coastal waters for the fisheries, and forests for the lumber industry. Over the years, a succession of staple exports - fish, furs, wheat, minerals, timber products- has made us one of the richest nations. The prosperity of Canada, then and now, is based on the exploitation of natural resources, and their export to foreign lands" (p. 11).

The Canadian economy is characterized by a unique regional diversity. Almost every region and province has been endowed with one or more natural resources, the exploitation of which contributes significantly to the regional or even national economy. For example, Quebec has mineral resources and extensive sources for hydroelectricity; Ontario forestry and mineral resources;

the Atlantic provinces have fisheries and the potential for development of off-shore hydro-carbon resources; the agriculturally rich Prairie provinces, Saskatchewan is also well-known for its potash and uranium, Manitoba for minerals and hydroelectricity, Alberta for oil, natural gas and coal; and British Columbia has forestry, minerals and fisheries.

The exploitation of natural resources for both domestic manufacturing and export dominates the Canadian economy. Our interest in this thesis is in the domestic economy and in particular, the way in which the resources are combined with capital and labour across the manufacturing sector. Identifying production technologies is a useful excercise for both academic and policy reasons. By achieving a better knowledge of the technical characteristics of production relationships, one is more able to determine and predict the effects of exogeneous events and various policy decisions. At the micro level, characterizing the production technology is important for designing and implementing combines policy, evaluating import quotas and determining needs, impacts, and incidence of subsidies. At the macro level they are important for all macro policy, monetary and fiscal, to determine not only impact but distribution. This determination is even more important today because the last (November, 1981) budget focuses on "resources" to be the main centre of growth in the Canadian economy.

1.A The Review of Manufacturing Production Studies

Increases in oil and energy prices stimulated interest in the adaptability of production to changes in relative input prices. Recent production studies reflect this development with their emphasis on the nature of the demand for energy in manufacturing production and manufacturers' response to its rising price. One of the main purposes of the recent energy demand studies is the estimation of parameters which are of special interest to economic policy analysts.[1] The most important parameters are elaticities of substitution and elasticities of demand. These studies, therefore, examine these elasticity parameters with particular attention to inter-energy fuel and energy-other input substitituion possibilities.

There are several Canadian studies (Fuss (1977), McRae (1978); McRae and Webster (1980), Denny et al.(1978); Denny et al. (1979); Cameron and Schwartz (1979)) which are concerned with the estimation of the translog model and which investigate the demand for energy in the Canadian manufacturing sectors using either regional or national data. Similar studies have been done for United States manufacturing (Berndt and Wood (1975), Humphrey and Moroney (1975), Halvorsen (1977), Hudson and Jorgenson (1974)). In addition, Griffin-Gregory (1976) and Pindyck (1979) deal with international cross section data. They too investigate manufacturing.

These studies focus on a number of parameters to describe the industry's technology which have important economic and policy implications. These parameters, as mentioned before, are own and cross elasticities of demand (ηii and ηij respectively) and elasticities of substituion (σij). These are key inputs for policy analysis since they indicate the nature of economic interrelations and can be used to predict the response to different events or policies- e.g. the impact of price changes on factor demand, particularly employment, via a simulation model.

As an example of the insights such parameters afford, consider a policy instrument such as an investment tax credit (ITC) which is sometimes suggested as a means of easing firms' adjustment to higher energy prices. The implementation of an ITC will result in lowering the price of capital which in turn will increase the quantity demanded. The magnitude of the impact, however, depends on the own elasticity of demand for capital (ηKK). For example, Denny et al. (1978) find that the own elasticity of demand for capital, is about half as much as that of the own elasticity of demand for energy. If σKE, the elasticity of substitution between capital and energy is positive, the implementation of an ITC will lead to a more capital intensive industry as capital will be substituted for energy, while a negative σKE indicates complementarity of capital and energy. In the same study Denny et al.(1978)

find that σKE is about -11.91, indicating that the implementation of an ITC can be expected to result in higher energy consumption in Canadian manufacturing. The positive σLK also obtained by Denny et al. indicate that an ITC may reduce employment while the positive σLE implies that employment will be stimulated by higher energy prices since labour and energy are substitutes. Other policy instruments can be similarly analyzed.

Fuss (1977) investigates demand for energy in Canadian manufacturing on a regional basis using a four input KLEM model (where K denotes capital, L denotes labour, E energy, and M materials). His model also permits interfuel substitution among six energy components (coal, liquified petroleum gas (lpg), fuel oil, natural gas, electricity and motor gasoline). A two-stage optimization procedure is utilized for estimation which is valid under the assumption of homothetic separability. The important findings of the study are that substantial interfuel substitution is possible, energy-aggregate input substitutability is moderate and that large increases in energy prices can be accommodated with only small output price increases. The elasticities of demand for other inputs with respect to changes in energy prices are quite small. The elasticities of demand for labour and capital with respect to a change in the price of energy are $\eta LE=0.043$ and $\eta KE=-0.004$.

Other Canadian studies use a similar four input KLEM model with regional or national data. McRae (1978) finds elasticities of demand for labour and capital with respect to a change in the price of energy to be 0.03 and 0.02 respectively for Ontario manufacturing. Using the same model McRae and Webster (1980) find these estimates to be -0.03 and 0.02 respectively. Using national data, however, they found ηLE and ηKE both to be 0.03 for the period 1962-73, and -0.04 and 0.06 respectively for the period 1962-76.

These elasticities have important implications and can be useful in analyzing the effects of changes in the prices of energy on the demand for labour and capital (ηLE and ηKE). Considering the elasticities reported by Fuss (1977), if the price of energy increases by 10 percent, they imply that the demand for labour may increase by more than 0.4 percent and that of capital decrease by about 0.04 percent. These effects are different from those suggested by McRae's (1978) result in that a similar increase in the price of energy would increase the demand for labour by 0.3 percent and increase the demand for capital by about 0.2 percent. Thus there is some disagreement between the two studies. On the other hand, there is agreement between McRae (1978), for Ontario manufacturing, and McRae and Webster (1980), for national manufacturing for the period (1962-74).

Similar price elasticities are reported by the U.S. studies. For U.S. manufacturing Berndt and Wood (1975), using a KLEM model, find the elasticities of demand for labour and capital with respect to a change in the price of energy to be about 0.03 and -0.14 respectively. Hudson and Jorgenson (1974) find them to be 0.04 and -0.02 respectively.

International studies report a wider range of elasticities. Pindyck's (1979, p. 177) international estimates of industrialized nations for these cross price elasticities of demand vary from -2.56 to 0.55. A similar comparison has also been made by Griffin-Gregory (1976,p. 852), where among others, the elasticities of demand for labour and capital with respect to a change in energy prices varies from 0.02 (U.S) to -0.15 (Belgium), and from -0.14 (U.S) to 0.17 (Belgium and Norway) respectively.

Elasticities of substitution between inputs are also reported by some of these studies. For the Canadian studies, Denny et al.(1978) find the elasticities of substitution between labour-energy (σLE) and capital-energy (σKE) to be 4.89 and -11.91 respectively. Fuss (1975) finds both of these elasticities to be positive.

For the U.S. studies the elasticitiy of substitution between labour and energy ranges from 0.65 (Berndt and Wood,

1975) to 2.16 (Hudson and Jorgenson, 1974) whereas the elasticity of substitution between capital and energy varies from -3.22 (Berndt and Wood, 1975) to -1.39 (Hudson and Jorgenson, 1974). For an international comparison see Griffin and Gregory (1976, p. 851) and Pindyck (1979, p. 177).

As to the implications of these results, a positive value of LE implies that energy and labour are substitutes and an increase in the price of energy will increase the demand for labour (given a relatively constant wage rate). Similarly, an increase in the wage rate may result in greater energy use in manufacturing.

It can be seen that for the Canadian studies, Denny et al. (1978) find a large negative value of KE, while Fuss (1975) finds a small positive value - conflicting evidence leading to different implications. For instance, in the former case the implication is that if the price of energy increases manufacturing would become much less capital intensive, while the positive KE suggests greater use of capital.

The usefulness of these results is obvious, although further work is needed before the estimates can be accepted with confidence. These results have specific implications about production decisions and provide information valuable to those responsible for designing public policies, such as an energy strategy. However, if it is desirable to adopt a strategy with regard to renewable or non-renewable (mineral)

resources, such a decision cannot be taken from the results based on the KLEM specification. In other words, using a KLEM model we cannot predict the nature of substitution possibilities among the natural resource components, labour and capital and their demand elasticities. Therefore, an alternative specification is called for.

1.B A Case For An Alternative Specification

Given the resource abundance of the Canadian economy, it is natural to study the use of these resources in the manufacturing sector. The importance of resources in manufacturing is obvious from the cost shares of the manufacturing sector. For example, for manufacturing over the 1961-1976 period, the average cost shares attributable to resources is more than 42%, of which the energy share is only a little more than 3%, the renewable resource share is about 18% and non-renewable resource share is about 21%. Thus one may consider a five input production model where in addition to traditional labour and capital inputs one may consider three different types of resource inputs (energy, renewable and non-renewable resources).

It is important to understand the role of resources in the manufacturing process not only because of their significance as an input but also because of the variability of their prices. While attention has focused recently on the energy input, other resource inputs representing a larger cost share have also experienced significant price

changes. For example, for the total manufacturing sector the average annual rate of change of energy prices for the period 1973-1976 is 21.9%, while for renewable and non-renewable resource prices these changes are 6.83% and 23.5% respectively. For the food industry these rates for the same period are 21.42% for energy price changes, 5.09% for renewable resource price changes, and 13.22% for non-renewable resource price changes.

How do manufacturers respond to these changes? What opportunities are there for substitution of labour and capital for resources and of renewable for non-renewable resource, etc.? Do current government tax and expenditure (or monetary) policies help or hinder such substitution possibilities? The answers to these questions are of special relevance if trends in resource prices portend greater resource scarcity either natural or managed.[2]

Some studies (Humphrey-Moroney (1975), Griffin and Gregory (1976)) specifically investigate substitutability among three inputs--capital, labour and natural resources. These two studies take natural resources into account but treat them at an aggregate level without disaggregating into energy, other basic resources-renewable, non-renewable, and other (manufactured, intermediate) material inputs. To our knowledge none of these studies have considered natural resources specifically as separate inputs.

The KLEM model defines materials as one of the inputs. Materials includes, however, all other resource components

except energy. Raw materials and finished intermediate products are not distinguished and hence their separate roles are not properly identified. This study is interested in investigating the role of resources more closely and to do so must disaggregate the material input. Natural resources are often a highly specific or unique input with a separate identity and a special importance in the production process. For example, forestry products or lumber and timber have a special significance in the wood industry and similarly, crude mineral oil as a factor of production in the petroleum and coal products industry. In the same fashion, grains, live animals and other agricultural products have a unique place in the food industry.

In order to provide the necessary analytical framework for our investigation a classification of natural resources is used as a starting point. Natural resources may be broadly classified as (a) renewable and (b) non-renewable resources, where non-renewable resources can be further classified as b(1) energy resources[3] and b(2) non-energy or other non-renewable resources.

A renewable resource is a flow resource which regenerates or recycles itself.[4] Ciriacy-Wantrup (1968) terms extractive resources as renewable resources if they exhibit economically significant rates of regeneration. There are various types of renewable resources of which fisheries, forests, farm produced agricultural commodities, furs and water resources are known as the important ones.[5]

Non-renewable resources , on the other hand, are those which are depletable over time.[6] For example, they include resources such as mineral ores, fossil fuels, natural gas or other types of mineral resources which do not regenerate themselves to any significant degree and whose artificial regeneration process or recyling is also limited by economics and nature.[7]

A non-renewable resource is also known as a stock resource which can eventually be depleted but possibly recycled.[8] Use in one period precludes use in a future period. Also the rate at which current exploitation occurs may reduce future availability by more than consumption, e.g. an oil pool. Therefore, the rate of exploitation of a stock resource is of special concern to economists since there is a finite time horizon over which such a resource can be utilized. The rate of use of such resources should be determined in an optimal fashion.

It follows from the above discussion that renewable and non-renewable resources have quite different characteristics that may affect their relative long term availability. In the absence of other developments (e.g. unanticipated shifts in demand or the supply of substitutes), one would expect renewable resource prices to increase less than the non-renewable resource prices since renewable resources can be replaced, while the non-renewable resources are gradually depleted. In actual situations technological development and new discoveries may disrupt the prediction of simple

models. As a casual observation we note that for the total manufacturing sector of the Canadian economy, the average annual rate of change of energy, renewable and non-renewable resource prices for the period 1961-1976 are 6.80%, 5.84%, and 7.47% respectively. Although it can hardly be claimed as conclusive evidence, a relatively smaller change in the price of renewable resources is noted.

Evidence of increasing resource scarcity is, to date, limited. Barnett (1979), following Barnett and Morse (1963), has demonstrated with U.S. and international data that in general there does not seem to be any evidence in support of increasing resource scarcity as measured by real unit costs.[9] However, in several selected cases the most recent data (1950-1972) appear to offer limited support for a weaker version of the resource scarcity hypotheses.[10] Smith (1979) using data from 1890 to 1957 has observed erratic relative price trends but has found no indication that the real price of resources has increased and that the (weak) scarcity hypothesis fails to be supported. Some differences of opinion occur due to controversy concerning the appropriate measurement of scarcity.

Despite uncertainty with respect to the direction of resource scarcity, resource prices vary considerably. How manufacturers respond to such movements is important in itself to understand short run response and the production technology. In addition, this reaction may suggest response to longer term trends in relative prices.

Therefore, given that renewable and non-renewable resources have quite distinct characteristics and that producers would be responsive to changes in their prices, it may be desirable, perhaps, even necessary to treat them as separate production inputs in order both to obtain a more appropriate representation of the production technology and to enable their proper consideration in resource management policy.

A comparison of the major findings of studies based on three and four inputs shows substantial disparities. For example, for the cross-section U.S. study based on a three input(L, K, N, where N denotes natural resources) model, Humphrey-Moroney (1975) found the elasticity of substituion between capital and natural resources as 1.34 for the food industry, while, for Ontario food manufacturing and using a four input (KLEM) model, McRae (1978) found the elasticity of substitution between capital and materials to be 0.23. Comparison among Canadian studies based on the (KLEM) model, however, do not show such a disparity. For example, for the same time period (1962-1973) and for the same Ontario food manufacturing McRae (1978) found ηKM to be 0.15, while Fuss (1979) found ηKM to be 0.162.

Therefore, it may be expected that the specification of a six input model, the inputs being labour, capital, energy, renewable resources, non-renewable resources and other materials, may provide estimates which differ from the KLEM model estimates. These estimates would provide information

specific to different types of resources and other materials. Since the main purpose of this study is to investigate the role of resources, we exclude other materials which may improve our ability to estimate the parameters.[11] The assumption behind this omission is that other materials bear a constant relationship with other inputs (technically, they are weakly separable from other inputs).

Usually a micro study is more appropriate than a macro study given the well-known problems of aggregation. Therefore, if possible, a micro study should be preferred to a macro study given the availability of data. We note, on the other hand, that studies based on a few individual firms may not be representative of the whole industry or even part of the industry. If we want to say things about the aggregate without investigating all firms, we may need to look at the aggregate data. In that case, though, we cannot say much about the individual firm behaviour. It is often difficult to obtain relevant data at the firm level or even at the level of three or four-digit industries (industry code number as classified by Statistics Canada). The present study is confined to two-digit industries.

The separate use of renewable and non-renewable resources from materials and the plan for a comparative study between the total and two-digit industries is clearly supported by Table 2 (cost share of inputs) in Appendix 2. It is evident that renewable and non-renwable resources are

not equally important in the two-digit industries and that resource intensity (renwable or non-renewable) varies significantly. Therefore, the demand for natural resources is not accurately reflected if material input is used as an aggregate index and also if the study is concerned only with the total manufacturing sector.

1.C Specification of Production Technology

The nature of the production stucture is an important issue. The value added specification has been called into question by authors of the previous production studies based on the four input-gross output specificatiuon (see Berndt and Wood, 1975). The present study, based on a five input-gross output specification, is an extension of the latter approach to the investigation of the structure of the production technology.

Most of the previous factor demand studies for the United States and Canada have considered real value-added as a function of labour (L) and capital (K). This implies that independence in the production relationship (in the technical sense, separability) of labour and capital use from decisions about the energy and materials or resource inputs has been implicitly assumed. But this may not be the case in reality. For example, Berndt and Wood (1975) found from the study of their KLEM model that energy and materials are not independent (separable) from L and K in the production relationship and therefore, the question is

raised as to the reliability of investment and factor demand studies for the U.S. based on a two factor (L, K) value-added specification. Also Denny et al.(1977) commented that estimates of productivity gains based on a real value-added output have to be re-examined.

Other characteristics of the production technology which should be examined are the independence of output in the determination of input (cost share) demand (in the technical context, homotheticity) and the independence of one or more inputs simultaneously from the rest of the inputs as well as output (technically, homothetic separability). Therefore, this study, based on a five input gross output specification will examine various questions relating to the structure of the production technology. In Chapter Two these questions are examined more thoroughly.

Having specified the aggregate production function, the flexible functional form is the most appropriate specification for the model. It implies few *a priori* restrictions on the function to be estimated and can be used to test those hypotheses in which we are interested. Cobb-Douglas and CES (constant elasticity of substitution) production functions were widely used by previous authors until the development of the flexible functional forms.[12] However, the limitations of the Cobb-Douglas and CES functions are that these functions impose rather severe *a priori* restrictions on the elasticity of substitution parameters, as well as other important parameters.

Furthermore, hypotheses about the independence of inputs or a group of inputs cannot be tested. Because flexible functional forms do not have such limitations, they are widely used today. The present study will use the translog model which is described in Chapter Two.

1.D Policy Related Questions

It has been argued in the previous section that an alternative specification to the KLEM type model is to specify a five input model and that this is an appropriate specification to investigate the role of resources. Questions arise concerning what happens if materials are disaggregated into renewable, non-renewable and other intermediate materials.[13] Will there be any significant change in the parameters characterizing the production technology? If so, what are the policy implications? The following policy related questions are expected to be of interest.

(1) How are resources, once separated from aggregate materials, related to other inputs? For example, in comparison with previous KLEM model results, questions of specific interest are whether σLR, σLNR, σKR, σKNR and σER are positive or negative and what are their magnitudes.

(2) Do firms substitute renewable and/ or non-renewable resources for energy? That is, are σER and σENR positive or negative?

(3) What are the magnitudes of demand elasticities?

(4) What is the pattern of the resource based and non-resource based industries in terms of demand and substitution elasticities?

(5) How do parameters vary across industries and over time? [14]

The major question is whether the five input production specification is an improvement on the representation of the Canadian manufacturing production technology. If so, as we believe to be the case, then how does the characterization appear? That is, what happens to σij and ηij and what are the trends?

The estimation problems encountered are treated later.

1.E Applying The Results to Policy Analysis

Elasticities of substitution (σij) and elasticities of demand (ηij) are important parameters for policy analysis. With them, the impact of exogenous or policy induced price changes (e.g. increased energy prices) on input demand can be predicted. Although the nature of the change can be determined from the elasticities, the full impacts are determined most thoroughly by a simulation study. Simulation analysis has been used to investigate the impact of changes in government policy instruments such as tax credits[15] or increases in prices of one or more energy components (like the political decision to increase the Canadian oil price to 75 percent of the world price level).

Since energy, renewable and non-renewable resources are the main focus of attention in this study, the questions of interest in the simulation section are as follows:

(1) What would be the impact of an increase in a factor's price on its own use and on that of other factors? Of major policy interest is the effect on employment but the effects on natural resources, energy and capital utilization are also of interest.

(2) What would be the effects of price changes on costs (after firms adjust)?

One of the important issues in input use in manufacturing production is to investigate productivity trends, productivity growth rates and factor intensities over time. Therefore, in our productivity analysis we are interested in the following questions:

(1) What are the trends in productivity growth rates of individual inputs and total factor productivity within industries?

(2) What are the trends of input requirement per unit of output across industries and over time?

The main objective of the present study, however, is to investigate the role and use of energy, renewable resources and non-renewable resources in Canadian two-digit manufacturing and in the total manufacturing sector. Furthermore, it is hoped that through estimation of the model at the two-digit level to gain insight as to the role of more specific though still collective, resource

inputs-for example, agricultural inputs to the food industry, forestry products to the wood industry, mineral oil to the petroleum sector etc.[16]

Recognizing the likehood of regional variations in production functions, it would be appropriate to investigate resource use at the regional level. But natural resource data for the manufacturing industries are available only at the national level from input-output tables since 1961. Thus this study is constrained to a national level. Some appreciation of regional differences may be realized by studying industry groupings characterizing specific regions. This approach is attempted here.

1.F Summary Statement of Objectives

The objective of this study will be accomplished through the following procedure:

(1) The selection of an appropriate functional structure for the manufacturing cost function using a real gross output specification which includes energy and both renewable and non-renewable resources.

(2) Testing the separability of various within industry factors of production such as the separability of labour, capital and energy from the resource sector.

(3) Examining the magnitudes of various elasticities of demand and elasticities of substitution, and comparing results obtained from the total and two-digit industries.

(4) Investigating the growth rate of total factor productivity. Examining the intensities of energy and resources and hence explaining trends of resource use.

(5) Undertaking a simulation study to investigate the impact of energy and resource price increases on input demands and the costs of the industry.

(6) Finally, comparing results with those of previous studies.

1.G Organization of the Dissertation

In Chapter Two the first section describes the framework of analysis that is adopted, and summarizes the major objectives of the production study. An appropriate technique for analysis is also introduced and discussed.

In section two of Chapter Two the general production function and its corresponding dual cost function are discussed. The general non-homothetic translog cost function model is then specified and considered as an appropriate (maintained) hypothesis.

In section three of Chapter Two conditions for testing alternative structures of the production technology such as strong or weak homotheticity of the maintained hypothesis are specified. Conditions for homothetic separability of energy and primary inputs (labour and capital) from the resource sector, and other separability conditions are also derived.

In Chapter Three problems of the measurement of inputs are discussed and different ways of measuring variables under different theoretical assumptions are justified.

In Chapter Four estimation problems relating to estimating the translog share equations are discussed and the appropriate method of estimation is presented. In order to test the hypotheses specified in Chapter Two, appropriate test statistics (either likelihood ratio or Wald tests) are derived and implemented.

In Chapter Five empirical results and analysis of Canadian manufacturing production relationships are provided on the basis of the preceeding considerations with particular emphasis given to industries of regional importance.

In Chapter Six, productivity measurement is discussed and productivity results are presented. Analysis of total factor productivity (TFP) is presented with attention focused on the fact that energy and resource inputs have different properties and impact differently upon each industry. Trends of factor intensity are analyzed highlighting regional importance.

In Chapter Seven a simulation procedure is developed and simulation results are presented and analyzed. Some econometric problems are encountered in simulation. These problems are discussed and corrected.

In Chapter Eight overall empirical results derived in the previous chapters are summarized and discussed in the

context of their policy implications. Directions for further research are outlined and discussed.

Data sources and data construction procedures are described in Appendices.

Footnotes to Chapter 1

1. Cameron, and Schwartz (1979), Denny et al. (1978a, 1978b, 1979), Fuss (1977), McRae (1978), McRae and Webster (1980).

2. According to Barnett and Morse (1963), for real economies, theory cannot answer whether or not there is increasing economic scarcity of natural resources. The answer must be based on evidence of factual data. However, for the United States prior to 1957, there is no evidence of economic scarcity in agriculture, minerals and the aggregate extractive industries, due to new discoveries, substitutability among inputs, sociotechnical improvements and other reasons.

3. Energy resources include electricity which may be treated as a partly renewable resource in that it may be produced from hydro-power.

4. Following Ciriacy-Wantrup's (1968) convention renewable resources are termed as flow resources.

5. According to Ciriacy-Wantrup, in some cases, ground water becomes non-renewable resource if there is no natural replenishment and surface flow is not available for artificial infiltration.

6. Non-renewable resources are also known as stock rsources which are depleted over time, through exploitation. However, as Ciriacy-Wantrup (1968) points out, some of the stock resources can be reduced even without exploitation, for example, oil and gas if changes take place through

seepage or any other natural means (for more discussion see Ciriacy-Wantrup, 1968).

7. See Peterson and Fisher (1979). Following Peterson and Fisher the distinction between renewable and non-renewable resources can also be formalized in terms of growth rate equations. For example, with mathematical notation, denoting X as the stock of the resource (say, fish stock), g(X) as the biological growth function, f(X,E,t) as the production or harvest function, where E, denotes efforts to obtain the resource and t, a technical change variable, they express the growth rate equation

$$\dot{X}=dX/dt=g(X)-f(X,E,t).$$

For a renewable resource $g(X)\neq 0$, indicating that the resource can be regenerated (reproduced), while for a non-renewable resource $g(X)=0$, implying that the resource cannot be regenerated. A renewable resource may in fact be depletable. Such is the case when there exists a critical zone which if the stock were reduced below that level it could not be restored economically.

8. According to Ciriacy-Wantrup resources are defined as "stock" resources if their total physical quantity does not increase significantly with time. Resources must be measured in appropriate physical units which are chosen in such a way that variations in quantity are taken into account.

Some non-renewable resources may be recycled although the natural resource will eventually be depleted, metals for

example. Non-renewable resources could be flow resources too--that is, sun light from burning (and consumption) of the fuels of the sun.

9. We have to keep in mind the limitations of Barnett's findings, namely, short periods of time, several cases of uncertain quality and the measure of scarcity. The unit real cost measure they use is often subject to criticisim. See Smith (1979).

10. Barnett proposes two scarcity hypotheses-strong and weak. The strong hypothesis states that the real cost of extractive products per unit will increase through time due to limitations in the available quantities and qualities of natural resources. The weak hypothesis suggests that while increasing resource scarcity does tend to increase real cost, this increase is more than offset by socio-technical progress or other favourable economy wide changes. See Barnett (1979).

11. This gives us more degrees of freedom. The share of other materials as an input is usually large but in a few cases the share is quite small. For example, primary, petroleum, and wood industries.

12. The Cobb-Douglas production function, for example, imposes the *a priori* restriction that the elasticity of substitution is always unity. Also the CES (constant elasticity of substitution) production function imposes an *a priori* restriction concerning the elasticity of substitution. Flexible functional forms are those functions

which do not impose *a priori* restrictions on the elasticity parameters (elasticity of substitution and elasticity of demand). The well-known flexible functions are the translog, generalized Leontief, generalized Cobb-Douglas and generalized square root quadratic. These are widely discussed in the recent literature. For example, studies by Berndt and Wood (1975), Diewert (1974), Fuss (1975,1977), Burgess (1974), Fuss et al. (1979), Denny et al. (1978), Humphrey and Moroney (1975), Halvorsen (1977), Hudson and Jorgenson (1974), Oum and Gillen (1980), McRae (1978), McRae and Webster (1980).

Flexible functional forms also allow for testing alternative structures of the technology (see Oum and Gillen (1980)). Also see the discussion, in Fuss and McFadden editors, Production Economics (1978) volume 1, p. 223. Denny et al. (1979) also discussed the relative advantages of using the translog flexible functional form.

13. Other intermediate materials are excluded in this study. This is based on the assumption that these are independent of other inputs. Humphrey and Moroney (1975) also made the similar assumption for their U.S. study.

14. This variation refers to the changes in the elasticity of substitution (or elasticity of demand) over time. These changes may be either changes in magnitude or changes in the sign of the parameters. For example, Cameron and Schwartz (1979) showed the changes in magnitude of the elasticity parameters, while Denny et al. (1979, p. xii) in

their Ontario manufacturing study, showed the changes of elasticity parameters from denoting substitutability (being positive) to complementarity (being negative).

15. Kesselman, Williamson and Berndt (1977) investigate the impact of investment tax credit (ITC).

16. Agricultural inputs to the food industry include grains, live animals, other agricultural products (e.g. fruits, vegetables, etc.). Grains itself is a collection of different kinds of crops such as wheat, barley, oats, rye, corn etc. Similarly, live animals (cattle, hogs, sheep, etc.) and poultry. Forestry products to the wood industry include lumber and timber, piles and poles, logs and bolts, etc.

Chapter 2. Methodology and The Model

2.A Methodology-The Framework of Analysis

This study examines the production relationship in Canadian manufacturing using a model incorporating both renewable and non-renewable resources in addition to the usual factors of production, capital, labour and energy. In order to accomplish this objective the multi-input production technology must be completely described. This is made possible by utilizing the dual relation between cost and production.

Given the production function there exists a corresponding cost function--the dual relation which exists between them was first established by Shephard (1953). Duality theory implies that if the firm minimizes costs and input prices are exogenous, and if the product transformation function, $T(Q,X)=0$, (where Q denotes output and X a vector of inputs), satisfies the usual regularity conditions (i.e. strictly convex isoquants), there exists a dual cost function $C(Q,P)$, where P is a price vector, which is as good a representation of the firm's production technology as the product transformation function and which satisfies the following regularity properties:

(1) C is non-negative, differentiable, non-decreasing, linearly homogeneous and concave on P for fixed non-negative output Q.

(2) C is strictly positive for non-zero output Q and is strictly increasing in Q.

That is, for well behaved relationships, one can deduce the structure of production technology directly from the cost function.

Past research (Diewert, 1971; Fuss and McFadden, 1978) has proven that through the application of the theorem of duality and the specification of a flexible functional form many *a priori* restrictions on the production set previously thought necessary are, in fact, not required. This is an advantage for any production study. Flexible functional forms which do not impose any *a priori* restrictions on the parameters, also allow for testing of several possible restrictions.

(1)Separability: This refers to the examination of the decentralization of firm's production decisions on input use. Separability implies that a firm's decision on the use of one or more inputs is independent of the rest of the inputs. For example, if the use of capital, labour and energy is independent of resources, this implies that changes in resource prices would not effect the use of other inputs. This issue is very important in production studies because it allows for the decomposition of production relationships into nested or additive components. Separability is of direct economic interest because it implies uniform behaviour of certain economic quantities and it allows for decentralization in decision making.[1]

(2) Homotheticity: This refers to the determination of the structure of the production technology. Technically this implies scale expansion paths which are rays through the origin.[2] Non-homotheticity, for example, will yield changing factor intensities with changes in scale.

(3) Consistency in aggregation: This implies the specification of technological structures that are invariant with respect to aggregation over commodities or economic units.[3] The aggregate index should be such that changes in any component of the list of components to be aggregated, should be reflected by changes (variations) in the aggregate index. For example, in the construction of an aggregate energy price index, changes in any component such as fuel oil or natural gas, should be realized consistently in the aggregate energy price index. The translog aggregation or the aggregation in terms of the homogeneous quadratic transformation function is an example of a consistent aggregator. This aggregation is consistent because such an aggregator utilizes variable input shares as weights in aggregation.[4]

Because it reduces the *a priori* restrictions and so permits the identification of a greater range of production relationships, the appropriate framework of analysis for production studies is the flexible functional form and that approach is adopted here.

One may use either production or cost functions for the empirical implementation of production studies. Usually a

system of derived input demand equations or a system of derived cost share equations is used to obtain the necessary, but unknown, parameters of the flexible function under consideration. By duality, either approach is possible.[4] Once input demand functions are derived the underlying technology of the production or the cost function can be directly inferred from the knowledge of the cost share or demand equations.

Most of the recent studies use the translog cost functions because of their relative ease in estimating share equations and deriving summary statistics.[5] For example, in the case of the translog production or cost function, all estimation equations are linear in logarithms which has computational advantages. Empirical studies (both producer and consumer demand studies) concerned with the choice of functional form also demonstrate that the translog function should often be preferred to other flexible forms.[6]

The non-homothetic translog cost function will be used as the maintained hypothesis in this study. Homotheticity and separability will be tested. In the specification of the translog function, a five input production model will be considered. The inputs are:

(1) Capital (K)

(2) Labour (L)

(3) Energy (E)

(4) Renewable resources (R)

(5) Non-renewable resources (NR)

where R and NR will be considered as aggregates of highly specific resource products. Given the specification of the production and the corresponding dual cost function, the input demand functions for capital, labour, energy, renewable and non-renewable resources will be derived and estimated using standard econometric techniques.

2.B Derivation of The General Model

From the duality correspondence between the production and cost functions, (Shephard, 1953), one can utilize either of two methods of deriving input demand and cost share equations.[7]

(a) Postulate a functional form for the production function satisfying certain regularity conditions, and then solve for the output constrained cost minimization problem which is used in deriving the input demand function and hence the cost share equations.

(b) Postulate a differentiable functional form for the industry cost function satisfying certain regularity conditions and obtain the derived input demand functions by applying Shephard's lemma.

The cost function approach is more commonly used than a production function approach in estimating parameters because it has the following advantages.[8]

(1) Estimation of parameters is much easier using a cost function than a produnction function.

(2) Tests on the elasticities of substitution between factor inputs are more easily carried out with the cost function approach since the required standard errors used in the tests are readily available.[9]

(3) The production function method uses inputs as arguments while cost function has output and input prices as arguments. Thus a cost minimization approach implicitly assumes enterpreneurs make decisions on factor use according to exogenous prices, which makes the factor levels endogenous decision variables.[10] Since the choice of inputs is endogenous to the firm and the production function approach is concerned with the direct use of inputs, this needs endogenous treatment of the input variables leading to a simultaneous estimation problem. The cost function approach avoids this problem, but requires that one assume that individual producers cannot influence prices.

(4) Given an exogenous shock on input prices, it would be easier to examine the impact on factor demands by using an estimated cost function than a production function.

(5) Recent productivity studies measure total factor productivity growth (TFP) as a sum of technical change effects and scale effects.[11] However, in order to estimate (TFP) or to separate scale effects from technical change effects an estimate of the scale elasticity is required. The scale elasticity can be obtained directly from an estimated cost function.

(6) Cost functions are homogeneous in prices regardless of the properties of homogeneity in the production function.[12]

(7) Prices are likely to be less collinear than inputs.[13] This implies that a cost function approach may encounter less multicollinearity than a production function approach.

Because of these and other advantages[14], the cost function is more widely used and will be used here in empirical estimation rather than the production function.[15]

2.B.1 Notation, Definition and Formulation of General Production and Cost Relationships

In this section the variables are defined and the general production relationships are specified.

Let $X^O=(X^R,E)$, where

X^O=Factors of production other than labour and capital.

$X^R=(R, NR)$

R=Renewable resources

NR=Non-renewable resources

E=Energy resources.

Let

L=Labour input

K=Capital input

Q=Output

C=Total cost.

Further let

$R=(R_1, R_2, \text{----} Rm_1)$

$NR=(NR_1, NR_2, \text{----} NRm_2)$

$E=(E_1, E_2, \text{----} Eh)$

$K=(K_1, K_2, K_3)$

$L=(L_1, L_2)$

where

Ri=i-th renewable resource input

$i=1, 2, \text{----} m_1$

NRi=i-th non-renewable resource input

$i=1, 2, \text{----} m_2$

Ei=i-th energy input

i=1, 2,---- h

Ki=i-th capital input

i=me, se, sb

me=Machinery and equipment

se=Structure (engineering)

sb=Structure (building)

Li=i-th labour input

i=p, np

p=production workers

np=non-production workers.

The five-input production function for an industry can be written as

$$Q=f(R_1, R_2, \text{----} Rm_1; NR_1, NR_2, \text{----} NRm_2; E_1, E_2, \text{---} Eh; Lp, Lnp; Kme, Kse, Ksb) \quad (1)$$

Assuming that $R(R_1, R_2, \text{---} Rm_1)$, $NR(NR_1, NR_2, \text{---} NRm_2)$, $E(E_1,$

E_2,--- Eh), L(Lp , Lnp) and K(Kme, Kse, Ksb) are aggregator functions and R, NR, E, L and K are aggregate inputs of renewable resources, non-renewable resources, energy, labour and capital respectively,[16] (1) can be written as

$$Q=f(R, NR, E, L, K) \qquad (2)$$

or

$$Q=f(X^O, L, K) \qquad (3)$$

Let $f(V)=\max(Q: X \varepsilon V(Q))$ where $X=(X^O, L, K)$ and $V(Q)$ is the input requirement set.

Diewert (1971) has shown that when V(Q) has the properties of location, closure, monotonicity, and concavity then f(V) has the properties of domain, monotonicity, continuity and concavity.[17]

The transformation function corresponding to the production function (3) can be written as

$$F(Q, X^O, L, K)=0 \qquad (4)$$

The firm choses a vector of optimal output Q and an optimal combination of inputs X^O, L, K simultaneously. The transformation function has properties similar to those of the production function.[18]

Given the production function (3), by the duality theorem the corresponding cost function can be written as

$$C=C(Q, P^O, Pl, Pk) \qquad (5)$$

The cost function is obtained from the following constrained minimization problem:

$$\min_{x} \sum_{i} PiXi$$

subject to $f(X^{O}, X1, Xk) \geq Q$ (6)

where Pi's and Xi's are the prices and quantities of i-th input.

Let $P=(P^{O}, P1, Pk)$. Then (5) can be written as

$C=C(Q, P)$ (7)

Costs are minimized for all $P \varepsilon \Omega^*$ in the strictly positive orthant, where Ω^* is a Cartesian product of the appropriate subspaces (e.g. $\Omega^*=\Omega^L x \Omega^K x \Omega^E x \Omega^R$ x Ω^{NR}), and $Q \varepsilon \mathbb{Q}$ is described by the cost function

$C(Q,P)=\min(P\ X: X \varepsilon V(Q))$. (8)

Here $X=(X^{O}, X1, Xk)=(R, NR, E, L, K)$, and V(Q) is the input requirement set, containing all the input bundles which can produce output (Q). That is, $V(Q)=(X: (X,Q)\varepsilon\mathbb{Q})$, $\mathbb{Q}$ is the production possibility set, the set of all feasible input-output combinations such that $Q=(X,Q$: X can yield Q). For the properties of V(Q) see Fuss et al. (1978, p. 226).

If the factor markets are not competitive, a cost function can still be defined by this formula with prices P interpreted as shadow or imputed prices.[19]

If V(Q) possesses required properties then C(Q, P) has the following properties.[20]

(a) Domain: C(Q, P) is a positive real-valued function defined for all positive prices P and all positive producible outputs, C(0, P)=0.

(b) Monotonicity: C(Q, P) is a non-decreasing function in output and tends to infinity as output tends to infinity. It is also non-decreasing in prices.

(c) Continuity: C(Q, P) is continuous from below in Q and continuous in P.

(d) Concavity: C(Q, P) is a concave function in P.

(e) Homogeneity: C(Q, P) is linear homogeneous in P.

(f) Differentiability: Differentiability is usually assumed in empirical investigations. In most empirical applications C(Q,P) is required to be twice differentiable in P. As such the cost function should possess the following derivative properties:

(i) $\frac{\partial C}{\partial P_i} = Xi$ Shephard's lemma

(ii) $$\frac{\partial^2 C}{\partial P_i \partial P_j} = \frac{\partial^2 C}{\partial P_j \partial P_i} \Leftrightarrow \frac{\partial X_i}{\partial P_j} = \frac{\partial X_j}{\partial P_i} \qquad \text{(symmetry)}$$

(9)

Property (i) can be used to generate systems of factor demand equations. Property (ii) is useful in reducing the number of parameters to be estimated.

The notion of differentiability can also be applied to the concavity property of the cost function. Accordingly, property (ii) can be expressed as the matrix $\frac{\partial^2 C}{\partial P_i \partial P_j}$ being negative semi-definite. This can be shown to be equivalent to the condition that the matrix of partial elasticities of substitution be negative semi-definite.[21] This means that for empirical verification of the well-behavedness of the cost function it is necessary and sufficient to test whether or not the determinants of the principal minors of the above matrix alternate in sign.[22]

2.B.2 Derivation of Industry's Unit Cost Function

In order to derive the unit cost function as a function of prices only, the following restrictions are required to be imposed on the general cost function (7)

(a) The cost function $C(Q, P)$ is completely strictly separable in various combinations of prices.

(b) The cost function C is positively linearly homogeneous in output Q.

(c) The cost function C is differentiable and strictly positively monotonic in (Q, P) and positively linearly homogeneous and concave in P.

By the theorem developed by Blackorby-Primont-Russel, (1978), the cost function (7) can be written as

$$C=H(Q)\cdot G(P) \qquad (10)$$

where G is an increasing function of P and G is differentiable, strictly positively monotonic, positively linear homogeneous and concave in P. $H(Q)$ is a function of Q, which is continuous, monotonically increasing, and such that $H(0)=0$, with H tending toward infinity. In most applications $H(Q)$ is assumed to be equal to Q and consequently the technology is linear homogeneous.[23] Therefore, the cost function (6) can be written as

$$C=Q\cdot G(P)$$

$$\text{or } C/Q=G(P)$$

$$\text{or } c=G(P) \qquad (11)$$

where $c=C/Q$. Equation (11) is thus a unit cost function.[24]

A mathematical derivation of the general cost function (7) and its special case (11) in terms of the translog formulation will be provided in the following section.

2.B.3 A Mathematical Specification of the General Model

In the translog formulation, the general model (6) as a function of five input prices PL, PL, PE, PR, PNR and output Q can be written as

$$\log(C)=\log(\alpha_0)+\sum_i \alpha \log(P_i)+1/2\sum_{ij}\sum\beta_{ij}\log(P_i)\log(p_j)$$
$$+\sum_i d_{iQ}\log(P_i)\log(Q)+\alpha_Q\log(Q)+1/2\ \beta_{QQ}(\log(Q))^2 \qquad (12)$$

$i,j=L,\ K,\ E,\ R,\ NR$

The translog cost function (12) is a second-order logarithmic Taylor series expansion of a twice differentiable analytic cost function around unity.[25]

Imposing the Hicks-Samuelson symmetry condition $\beta_{ij}=\beta_{ji}$, the coeffients of cross-product terms of $\log(P_i)$ and $\log(P_j)$ can be written as

$$\beta=\begin{bmatrix} \beta_{LL} & \beta_{LK} & \beta_{LE} & \beta_{LR} & \beta_{LNR} \\ \beta_{LK} & \beta_{KK} & \beta_{KE} & \beta_{KR} & \beta_{KNR} \\ \beta_{LE} & \beta_{KE} & \beta_{EE} & \beta_{ER} & \beta_{ENR} \\ \beta_{LR} & \beta_{KR} & \beta_{ER} & \beta_{RR} & \beta_{RNR} \\ \beta_{LNR} & \beta_{KNR} & \beta_{ENR} & \beta_{RNR} & \beta_{NNR} \end{bmatrix} \qquad (13)$$

where β_{ii}, $i=L,\ K,\ E,\ R,\ NR$ are the diagonal elements and β_{ij} $i\neq j$, $\beta_{ij}=\beta_{ji}$ are off-diagonal elements of β. It is obvious that the symmetry restrictions reduce the parameters of this matrix from 25 to 15.

The function must satisfy the following conditions:

(i) Linear homogeneity in prices: That is, when all factor prices are doubled, the total cost will double. It can be shown that linear homogeneity implies the following restrictions:

$$\sum_i \alpha_i = 1, \ \sum_i \beta_{ij} = 0, \ \sum_i \beta_{ji} = 0, \ \sum_i d_{iQ} = 0, \text{ for all } i,j \qquad (14)$$

(ii) Monotonicity: The function must be an increasing function of input prices. That is,

$$\frac{\partial \log C}{\partial \log P_i} \geq 0 \ , \ i = L,\ K,\ E,\ R,\ NR$$

Imposing the restrictions of linear homogeneity, the translog cost function can be written as

$$\begin{aligned} \log(C) = {} & \log(\alpha_0) + \sum_{i,i \neq j} \alpha_i \log(P_i/P_j) + \log(P_j) \\ & + (1/2) \sum_{ij}\sum \beta_{ij} \log(P_i/P_j) + \sum_i d_{iQ} \log(Q) \log(P_i/P_j) \\ & + \alpha_Q \log(Q) + (1/2) \beta_{QQ} (\log(Q))^2 \end{aligned} \qquad (15)$$

2.B.4 The Translog Unit Cost Function

The translog unit cost function can be specified as

$$\log(c) = \log\alpha_0 + \sum_i \alpha_i \log(P_i) + 1/2 \sum_{ij}\sum \beta_{ij} \log(P_i) \log(P_j) \qquad (16)$$

where $c=C/Q$, C is the total cost of production, Q is the output.

Imposing linear homogeneity and symmetry restrictions ($\sum_i \alpha_i = 1$, $\sum_i \beta_{ij} = \sum_j \beta_{ji} = 0$, $\beta_{ij} = \beta_{ji}$ the translog unit cost function can be written as

$$\begin{aligned} \log(c) = {} & \log\alpha_0 + \sum_{i,i \neq j} \alpha_i \log(P_i/P_j) + \log(P_j) \\ & + 1/2 \sum_{ij}\sum \beta_{ij} \log(P_i/P_j) \end{aligned} \qquad (17)$$

In order to derive the input demand function from the non-homothetic model (12), apply Shephard's lemma

$$X_i = \frac{\partial C}{\partial P_i} \quad \text{where } X_i = \text{i-th input} \qquad (18)$$

$$X_i = \frac{\partial C}{\partial P_i} = C(.)/P_i.$$

$$X_i = C(.)/\ P_i[(\alpha_i + \sum_i \beta_{ij} \log(P_j) + d_{iQ} \log(Q)] \text{ or}$$

$$P_i X_i / C = \alpha_i + \sum_i \beta_{ij} \log(P_j) + d_{iQ} \log(Q) \qquad (19)$$

Hence the input demand or the cost share equation of the i-th input for the industry is given by

$$Si = \alpha_i + \sum_j \beta_{ij} \log(P_j) + d_{iQ} \log(Q) \qquad (20)$$

where $S_i = P_i X_i / C$

i=L, K, E, R, NR and j=L, K, E, R, NR.

Due to the homogeneity constraint, only (n-1) share equations are lineary independent and can be estimated simultaneously. Therefore, one of the five share equations is to be deleted leaving a system of five equations (four share equations and the translog cost function) to be estimated using either a non-linear multivariate system estimator or Zellner's seemingly unrelated regression technique.[26]

2.B.5 Elasticities of Substitution and Elasticities of Factor Demand

2.B.5.1 Elasticities of Substitution

The elasticities of substitution (σ_{ij}'s) are specific to pairs of inputs (e.g. between inputs i and j) and as such summarizes economic interrelations between two inputs only. In a two input specification, (σ_{ij}) must denote substitutability while in a more than two input case at least one of them may denote either substitutability or complementarity.

Estimates of partial elasticities of substitution σ_{ij} can be obtained directly from the parameters of the cost function as follows:

$$\sigma_{ij} = \frac{\sum_i P_i X_i}{X_i X_j} \quad \frac{\partial^2 C}{\partial P_i \partial P_j} \tag{21}$$

This was originally proved for the homogeneous function by Uzawa (1962). Binswanger (1974) has given a proof of (21) which does not depend on homogeneity.

The Allen-Uzawa partial elasticity of substitution between input i and j can be written as

$$\sigma_{ij}=CC_{ij}/C_iC_j \text{ where } C_i= \frac{\partial C}{\partial P_i}$$

$$C_j= \frac{\partial C}{\partial P_i} \text{ and } C_{ij}= \frac{\partial^2 C}{\partial P_i \partial P_j} \tag{22}$$

For the translog cost function the parameters β_{ij} can be shown to be related to σ_{ij} and the factor shares as follows:

(i) $\sigma_{ij}=1+\beta_{ij}/S_iS_j$ for all i, j $i\neq j$

(ii) $\sigma_{ii}= (\beta_{ii}+S_i^2 -S_i)/S_i^2$ for all i

(23)

The above expressions show that σ_{ij}, (for all i and j) are functions of factor shares and input coeffients.

2.B.5.2 Elasticities of Factor Demand

The elasticities of factor demand can be referred to as the own price elasticity η_{ii}, the responsiveness of the i-th input demand due to own price changes, and cross price elasticity (η_{ij}), the responsiveness of the i-th input demand due to a change in j-th input price. These elasticities can be either partial price elasticities or total price elasticities.

Partial price elasticities are those which account only for substitution between inputs, assuming that the output effect is constant. Total price elasticities, on the other hand, account for both substitution and output effects, Marshallian elasticities are examples of total elasticities.

For the translog cost function the partial elasticities of factor demand are given by

(iii) $\eta_{ij}=\sigma_{ij}s_j$ (cross price elasticity)

(iv) $\eta_{ii}=\sigma_{ii}s_i$ (own price elasticity)

(25)

The total own price elasticity for the i-th input is given by

η^*_{ii}=dlog(Xi)/dlog(Pi), where η^*_{ii} denotes total own price elasticity of the i-th input

$$\eta^*_{ii}=Pi/Xi\left[\partial X_i/\partial P_i \mid Q = \text{constant} + \partial X_i/\partial Q \cdot \partial Q/\partial P_Q \cdot \partial P_Q/\partial P_i\right] \tag{26}$$

where Q is the total output, and P_Q is the price index for output.

Since the output price P_Q is given by the homothetic translog cost function with constant returns to scale

$$\log(P_Q)=\alpha_c+\sum_i\alpha_i\log(P_i)+1/2\sum_{ij}\sum\beta_{ij}\log(P_i)\log(P_j), \quad \partial P_Q/\partial P_i \tag{27}$$

is found to be equal to $(P_Q/P_i)S_i$, where S_i is the i-th input cost share. This implies

$$\eta^*_{ii}=\eta_{ii}+\partial X_i/\partial Q \cdot \frac{\partial Q}{\partial P_Q} \cdot (P_Q/X_i)S_i$$

$$=\eta_{ii}+\partial X_i/\partial P_Q \cdot (P_Q/X_i)S_i$$

$\eta^*_{ii}=\eta_{ii}+\eta_{iQ} \cdot S_i$

Similarly, the total cross price elasticities for each input can be obtained (see Pindyck, 1979) as

$\eta^*_{ij}=\eta_{ij}+\eta_{jQ} \; S_i$

Since information concerning η_{iQ} and η_{jQ} are not known to us, total elasticities are not estimated in this study.[27]

The properties of partial σ_{ij} and partial η_{ij} are given as follows:

(1) $\sigma_{ij}=\sigma_{ji}$ follows from (1) since $\beta_{ij}=\beta_{ji}$

(2) $\sigma_{ii}<0$ which is one of the required conditions for concavity of the cost function.

(3) $\sigma_{ij}\gtrless 0$, can be positive, negative or zero.

$\sigma_{ij}=0$, implies factors i and j are independent,

$\sigma_{ij}>0$, implies factors i and j are substitutes,

$\sigma_{ij}<0$, implies factors i and j are complements

(4) $\eta_{ii}<0$, follows from the law of demand

(5) $\eta_{ij}\gtrless 0$ can be elastic, inelastic or very inelastic.

(6) $\eta_{ij}\neq\eta_{ji}$ follows from (iii).

2.C Separability, Homotheticity and Homothetic Separability

2.C.1 Separability of Inputs

In the specification of the five input general cost function in section (B) it has been assumed that L(.), K(.), E(.), R(.) and NR(.) are aggregator functions of their respective input components and L, K, E, R, and NR are aggregate inputs of labour, capital, energy, renewable and non-renewable resources respectively. The question arises

whether any one of these aggregate inputs or any combination of them are separable (groupwise independent) in the structure of production technology or not. Separability in turn will imply decentralization (that is, ability of decision making in stages) of firm's decisions on input use.[28] Therefore, it is of interest to investigate the separability of any input or any combination of them from the rest of the inputs. Of particular interest in the present study, is the question of the separability of labour (L), capital (K), and energy (E) from the resource sector (R, NR) and separability of R and NR within the resource sector. There are also other types of separability hypotheses which can be empirically tested.[29] The meaning of the separability of L, K and E from R and NR is that changes in the prices of L, K and E and their component prices will not affect the firm's behaviour with respect to uses of R and NR. In other words, firms' decisions in the event of changes in prices of L, K and E are independent of decisions on the uses of R and NR.

According to the production technology this implies that marginal rates of technical substitution or the ratio of marginal products between any pair of elements in the vectors (L1, L2), (K1, K2, K3) and (E1, E2,-----E7) are independent of R and NR. This is the Leontief-Sono definition of separability.[30] This independence of one or more inputs from the rest of the inputs of a production specification has two different connotations; complete

independence and independence in a weak sense. The case of complete independence is known as strong separability and that of weak independence is known as weak separability.

The definition and meaning of separability with respect to the production function is the same for the corresponding dual cost function (see Fuss and MacFadden 1978, p 245). In the case of the cost function, input prices are of concern rather than input quantities. Since the present study is concerned with the issue of energy and resource use the following separability hypotheses will be of interest:

(i) The strong and weak separability of L, K, E from (R, NR).

(ii) The strong and weak separability of R, NR from E.

(iii) The separability between R and NR.

The derivation of the actual strong and weak separability conditions with respect to the specified translog cost function is provided in the following sub-sections.

2.C.2 Weak Separability of L, K, E from the Resource Sector (R, NR)

A cost function that is separable in (L, K, E) from (R, NR) can be written in the form:

$$C=f(G(P_L, P_K, P_E), P_R, P_{NR}, Q) \qquad (28)$$

such that

(i) $\frac{\partial C}{\partial P_i}=\frac{\partial f}{\partial G}\cdot\frac{\partial G}{\partial P_i}$, i=L, K, E

$$(ii)\ \frac{\partial^2 C}{\partial P_i \partial P_j} = \frac{\partial^2 f}{\partial G \partial P_j}\frac{\partial G}{\partial P_i} + \frac{\partial f}{\partial G}\frac{\partial^2 G}{\partial P_i \partial P_j}$$

i=L, K, E and j=R, NR

The second term in (ii) vanishes since $\partial G/\partial P_i$ is not a function of p_j (j=R, NR). Therefore, (ii) becomes

$$(ii)'\ \frac{\partial^2 C}{\partial P_i \partial P_j} = \frac{\partial^2 f}{\partial G \partial P_j}\frac{\partial G}{\partial P_i} \qquad (29)$$

The relation (ii)' must hold for the separability of P_i (i=L, K, E) from P_j (j=R, NR) and if so at the point of approximation, (e.g. at $\log(P_i)=1$, i=L, K, E, $\log(P_j)=1$, j=R, NR) where the first and second partial derivatives can be identified with parameters of the translog cost function. That is,

$$\frac{\partial^2 \log C}{\partial \log P_i \partial \log P_j} = \beta_{ij},\ \frac{\partial \log C}{\partial \log P_i} = \alpha_i \qquad (30)$$

Therefore, in order for the separability of P_i (i=L, K, E) from P_j (j=R, NR) to hold the parameters of the cost function must satisfy the following conditions, obtained by dividing (ii)' by (i), (for the translog form)

$$\frac{\partial^2 \log C}{\partial \log P_i \partial \log P_j} \Big/ \frac{\partial \log C}{\partial \log P_i} = \rho_j \qquad (31)$$

$$\text{or } \beta_{ij}/\alpha_i = \rho_j \qquad (32)$$

Where ρ_j is a constant, being independent of i, equation (32) can be written as

$$\beta_{ij}=\alpha_i\rho_j \quad \text{where i=L, K, E and j=R, NR} \qquad (33)$$

showing a proportional relationship between the second order coefficient of the $\log(P_j)$ variables (j=R, NR) and the first

order coefficient of the $\log(P_i)$ variables (i=L, K, E). For the given example, conditions (32) implies four independent restrictions. These conditions are more general in nature than those of Denny and Fuss (1977) in that different types of separability conditions can be obtained using this procedure.[21] This also reduces the number of unknown parameters to be estimated. For further discussion and derivation of separability conditions see Jorgenson and Lau (1975), and Oum and Gillen (1980).

2.C.3 Strong Separability of L, K, E from the Resource Sector(R, NR)

Strong separability of L, K, E from (R, NR) implies that L, K, E must be completely independent of R, NR, which in terms of parameters of the cost function implies

$\beta_{ij}=0$ when i=L, K, E and j=R, NR (34)

In terms of weak separability conditions (33) this means that both β_{ij} and ρ_j must equal zero.

The specification of the underlying cost function implies

$\log(C)=\log f_1(P_i, Q)+\log f_2(P_j, Q)$

$C=f_1(P_i, Q).f_2(P_j, Q)$

i=L, K, E and j=R, NR

It is clear from conditions (33) and (34) that (33) implies a proportional relationship between the second order coefficients β_{ij} and the first order coefficient α_i, while (34) implies complete independence or additivity.

The differential treatment of separability as being strong and weak has important implications with respect to aggregation and substitution possibilities among inputs. For example, a consistent aggregate index of a subset of inputs exists if and only if the subset of inputs is weakly separable from all other inputs.[32] Berndt and Christenson (1973) have shown the different implication of weak and strong separability by proving various theorems. In particular, it is interesting to note that complete strong separability of the production function at any point in input space is necessary and sufficient for all proper Allen partial elasticities of substitution (AES) σ_{ij} to be equal at that point.[33]

2.C.4 Other Separability Conditions

2.C.4.1 The Separability of R and NR from E

The weak separability conditions for this hypothesis can be obtained using the general conditions $\beta_{ij}=\alpha_i\rho_j$ where i=R, NR and j=E.

The conditions are

$$\begin{aligned}
&\beta_{RE}=\alpha_R\rho_E \\
&\beta_{NRE}=\alpha_{NR}\rho_E \qquad\qquad\qquad\qquad (35)\\
&\beta_{RE}=\beta_{ER} \\
&\beta_{NRE}=\beta_{ENR} \qquad \text{(by symmetry)}
\end{aligned}$$

Equations (35) imply, using symmetry conditions,

$\beta_{ENR}\,\alpha_R-\beta_{ER}\alpha_{NR}=0$ (one independent restriction)

The strong separability of R and NR from E implies $\beta_{ER}=0$ and $\beta_{ENR}=0$. The mathematical specification of weak separability of (R, NR) from E is

$$C=G(g_1(P_R, P_{NR}), P_L, P_K, Q, g_2(P_E)) \qquad (36)$$

2.C.4.2 The Separability Between R, NR

The strong separability between R and NR implies that $\beta_{RNR}=0$ with one restriction. The underlying specification of the cost function is given by

$$C=G(g_1(P_R), P_L, P_K, P_E, Q, g_2(P_{NR})) \qquad (37)$$

2.C.5 Homotheticity-- The Structure of the Cost Function

The translog cost function (equation 12) presented in section B is a non-homothetic cost function and is the maintained hypothesis of this study. Shephard(1970) defined a homothetic function as a function that is a positive monotonic transformation of a linear homogeneous function. Technically, homotheticity implies scale expansion paths which are rays through the origin. A homothetic or a linear homogeneous cost function, which is a relatively simpler form, is most frequently used in empirical studies. The main reason for this is computational efficiency because fewer parameters need to be estimated. However, before using that simplified functional form, it is desirable to test the specification. The conditions for testing such a specification are derived below.

2.C.5.1 Weak Homotheticity

The structure of a homothetic production technology can be either weakly homothetic or strongly homothetic. Weak

homotheticity implies that input prices are independent of output in determining the input demand. In other words, the ratio of any two factor demand equations is independent of output level (Denny and May, 1978). Strong homotheticity on the other hand, implies, in addition to the above weak homotheticity condition, that the elasticity of total or average cost with respect to output is independent of factor prices (Denny and May, 1978).

Given that weak and strong homotheticity imply different economic properties it is important to investigate whether a production structure is either weakly homothetic or strongly homothetic. This also indicates the actual nature of the production technology.

The dual cost function equation (6), of section B implies a weakly homothetic production function F(X), X=L, K, E, R, NR, if it can be written in the form

$$C=f(G(P_L, P_K, P_E, P_R, P_{NR}), h(Q)) \qquad (38)$$

where h(Q) is a function of output(Q) only. That is,

$$C=f(G(P), Q) \qquad (39)$$

assuming, for simplicity, that h(Q)=Q and $P=(P_L, P_K, P_E, P_R, P_{NR})$, a vector of prices only, such that

$$\text{(i)} \quad \frac{\partial C}{\partial P_i} = \frac{\partial f}{\partial G}\cdot\frac{\partial G}{\partial P_i} \quad i=L, K, E, R, NR$$

$$\text{(ii)} \quad \frac{\partial^2 C}{\partial P_i \partial Q} = \frac{\partial^2 f}{\partial G \partial Q}\cdot\frac{\partial G}{\partial P_i} + \frac{\partial f}{\partial G}\cdot\frac{\partial^2 G}{\partial P_i \partial Q} \qquad (40)$$

The second term in (ii) is zero since $\frac{\partial^2 G}{\partial P_i \partial Q}$ is zero $(\frac{\partial G}{\partial P_i})$

not being a function of Q). Therefore, (ii) can be written as

$$(ii)' \quad \frac{\partial^2 C}{\partial P_i \partial Q} = \frac{\partial^2 f}{\partial G \partial Q} \frac{\partial G}{\partial P_i} = \frac{\partial^2 f}{\partial P_i \partial Q} \qquad (41)$$

The relation (41) must hold for the separability of P_i from Q and if so at the point of approximation, (e.g. $\log(P_i)=1$, i=L, K, E, R, NR, $\log(Q)=1$) where first and second partial derivatives can be identified with parameters of the translog cost function. That is,

$$\frac{\partial^2 \log C}{\partial \log P_i \log Q} = d_{iQ}, \quad \frac{\partial \log C}{\partial \log P_i} = \alpha_i \qquad (42)$$

Therefore, for the groupwise separability of prices from output, the parameters of the translog cost function must satisfy the constraints:

$$d_{iQ}/\alpha_i = \rho_Q \text{ or } d_{iQ} = \alpha_i \rho_Q \qquad (43)$$

where ρ_Q is a constant given by

$$\rho_Q = \frac{\partial^2 \log C}{\partial \log G \partial \log Q} / \frac{\partial \log C}{\partial \log G}$$

For the present example, condition (43) represent four independent restrictions.

We note that the form (32) implies that the ratio of any two factor demands is independent of output (Denny and May, 1978).

Since by Shephard's Lemma, we have

$$X_i = \frac{\partial f(G(P), Q)}{\partial P_i}$$

Which by using (38), can be written as

$$X_i = \frac{\partial f}{\partial G} \cdot \frac{\partial G}{\partial P_i}$$

With the first term being independent of i and the second

term being independent of output, the above result follows. Denny and May, (1978) also pointed out that the dual production function, in this case is no longer a positive monotonic transformation to a linear homogeneous production function.

5.C.5.2 Strong Homotheticity

Strong homotheticity implies complete independence of input prices from the level of output. In investigating the nature of the production technology, it is important to know if it is strongly homothetic or not. As was mentioned earlier, a strong homothetic function is much easier to estimate.

In vector notation the non-homothetic cost function (4) can be written as

$$C=C(P, Q) \qquad (44)$$

where

$$P=(P_L, P_K, P_E, P_R, P_{NR})$$

A production technology is said to be homothetic (Shephard, 1970) if the above non-homothetic function (44) can be written as

$$C=f(P)\cdot H(Q) \qquad (45)$$

In logarithmic form

$$\log(C)=\log f(P)+\log H(Q) \qquad (46)$$

This implies that the functions f and H are additive and in turn implies the following restrictions on the parameters of the non-homothetic translog cost function

$d_{iQ}=0$, i=L, K, E, R, NR (47)

With respect to the translog share equations, equation (47) implies four independent restrictions.[34]

Conditions from (43) show that weak separability implies a constant proportional relationship between the second order coefficient (d_{iQ}) of the interaction term ($\log(P_i) \cdot \log(Q)$) and the first order coefficient (α_i) of the i-th input price, while strong homotheticity or condition (47) implies complete independence or additivity.

2.C.6 Homothetic Separability

2.C.6.1 Weak Homothetic Separability

A translog cost function will be said to be approximately weakly separable if it simultaneously satisfies both homotheticity conditions as well as the conditions for the separability of a group of inputs from one or more of the other inputs. For example, the weak homothetic separability of (L, K, E) from (R, NR) implies the following two sets of constraints:[35]

(a) $\beta_{ij}=\alpha_i\rho_j$ i=L, K, E and j=R, NR

(four independent restrictions)

(b) $d_{iQ}=\alpha_i$ i=L, K, E

(two independent restrictions)

The derivations of conditions (a) and (b) are shown above.

For the case of a four input non-homothetic translog cost function ($C=f(P_L, P_K, P_E, P_R, Q)$ or $C=f(P_L, P_K, P_E, P_{NR}, Q)$), the homothetic separability of L, K, E from R or NR implies the following two sets of conditions.

(a) $\beta_{ij}=\alpha_i\rho_j$ i=L, K, E and j=R or NR

(two independent constraints)

(b) $d_{iQ}=\alpha_i\rho_Q$ i=L, K, E (48)

(two independent constraints)

In terms of the specification of the cost function this leads to the following form.[35]

$C=g(h(P_L, P_K, P_E), P_R, Q)$ or

$C=g(h(P_L, P_K, P_E), P_{NR}, Q)$ (49)

In either case $h(P_L, P_K, P_E)$ implies within homotheticity of L, K, E which in turn implies condition (b) and given this, homothetic separability of L, K, E from R or NR implies condition (a).

2.C.6.2 Strong Homothetic Separability

Following the same argument as in the case of strong separability, that of additivity or of independence, the strong homothetic separability conditions can be written as

$\beta_{ij}=0$ i=L, K, E and j=R, NR

(six independent restrictions)

$d_{iQ}=0$ i=L, K, E (50)

(three independent restrictions)

For the four-input cost function (L, K, E, R) or (L, K, E, NR) the strong homothetic separability conditions are as follows:

$\beta_{ij}=0$ i=L, K, E and j=R or NR

(three independent restrictions)

$d_{iQ}=0 \quad i=L, K, E \qquad (51)$

(three independent restrictions)

In the previous sections all conditions necessary to impose on the general non-homothetic cost function are derived for the purposes of showing how proposed hypotheses may be tested. These tests are particularly important in a production study which wishes to examine the true production relationship rather than one specified *a priori*. As such the most important structural peculiarities inherent in production set (that is, homotheticity, separability, both weak and strong) are outlined.

Footnotes to Chapter 2

1. See Fuss and McFadden (1978), volume 1, p. 221.

2. Ibid, p. 222.

3. Ibid, p. 222.

4. See Diewert (1974a) also Danielson (1974) p. 184.

5. For detailed discussion see Binswanger (1974b).

6. See Oum and Gillen (1980).

7. See Oum (1979).

8. See Binswanger (1974b).

9. For example, in the case of the translog cost function, elasticities of substitution σij is Given by

$$\sigma ij = 1 + \beta_{ij}/S_i S_j,$$

where β_{ij} are the translog parameters and S_i and S_j are cost shares. Assuming that S_i and S_j are non-stochastic, the standard error of σij can be obtained as

$$S.E.\sigma ij = S.E.(\beta_{ij})/S_i S_j.$$

On the other hand, for the production function, the estimation of the variance of σij is quite complicated. For the calculation of the variance of σij in the case of the production function see Humphrey and Moroney (1975).

10. This implies optimal determination of input level.

11. See Denny et al. (1979), p. 29. Also See Gillen and Oum (1980) p. 114 (a measure of the percentage change in productivity).

12. See Binswanger (1974b).

13. This is more likely to be so in the case of time series than cross-section data. Laumas and Williams (1981),

p. 326 also argue that multicollinearity problems are inherent in the production function approach due to high correlation between inputs (which are endogeneous to the firm) and less serious in the cost function approach since prices are determined in separate factor markets. However, it was cautioned that this may not always be the case. In fact, the exact relationship depends on the statistical behaviour of related variables.

14. For other advantages, see Binswanger (1974b).

15. The production function is more useful for technological analysis while the cost function is more useful for policy related analysis. The reason for this is that the production function is more concerned with the underlying technology and is constrained to be along a given isoquant while the cost function is concerned with movements from one optimizing point to another in response to price signals.

16. This implies a weakly separable (independent) production structure. See Fuss (1977), pp. 90-91.

17. See Fuss and McFadden (1978), volume 1. pp. 225-229.

18. Ibid, p. 227. Also see Diewert (1974a).

19. Ibid, p. 228.

20. Ibid, p. 227.

21. See Binswanger (1974a).

22. See Rao (1973), p. 37.

23. See Denny et al. (1978), p.302.

24. See also Diewert (1974), p. 156 for derivation of unit cost function.

25. The Taylor series expansion can be around any given constant, in particular, it may be the mean or unity. For more on the question regarding the approximation or exactness of the translog function see Laumas and Williams (1981), p. 328 (footnote 11), Fuss (1978), Oum and Gillen (1980).

26. See Kmenta (1971), p. 518.

27. These responses could be generated through simulation. For example, see Kesselman et al. (1977) and Denny et al. (1978). They assume some given values of η_{iQ} and examine the effects of price changes.

28. That is, in such a situation, the use of a group of inputs (e.g. resources, R and NR) is independent of the use of other inputs (e.g. L, K, E, etc.). Thus in one stage the firm decides on the use of a group of inputs (say, L, K and E) and then decides on the use of the other set, say, resources. According to Fuss and McFadden (1978), volume 1, p. 244,

> "Historically, separability has played an important role in the specification of functional forms: The Cobb-Douglas and CES functions are explicitly strongly separable. Hanoch's (1971) CRESH-CDE class of functions is implicitly strongly separable. Sato's (1967) nested CES specification is strongly

separable with respect to the highest level partition and then strongly separable within each sub-aggregate."

29. See Jorgenson and Lau (1975), Oum and Gillen (1980).

30. In mathematical notation (following Blackorby et al. (1978)) separability can be defined as follows:

Let X be the vector of inputs and f(X) be the production function, then f(X) has the following characteristics:

(1) f(X) is twice differentiable

(2) $f_i(X) = \frac{\partial f}{\partial P_i} > 0$, for all $X \varepsilon \Omega^n$, i=L, K, E, R and NR

where Ω^n=a Cartesian product of the appropriate subspaces. That is,

$$\Omega^n = \Omega^{(L)} \times \Omega^{(K)} \times \Omega^{(E)} \times \Omega^{(R)} \times \Omega^{(NR)}$$

Then the separability of variables X_i and X_j from X_K can be defined as

$$\frac{\partial(f_i(x)/f_j(x))}{\partial x_K} = 0, \quad \underline{\text{for all}} \quad x \;\varepsilon\; \Omega^n$$

That is, the pair of variables (X_i, X_j) is separable from X_K if the marginal rate of substitution between X_i and X_j are independent of X_K. In terms of cross-partial differentiation the pair of variables (X_i, X_j) is separable from X_K if

$$\frac{f_{iK}(x)}{f_i(x)} = \frac{f_{jK}(x)}{f_i(x)}$$

where $f_{iK}(x) = \frac{\partial f_i(x)}{\partial x_K}$, $\quad f_i(x) = \frac{\partial f}{\partial X_i}$

$f_{jK}(x) = \frac{\partial f_j(x)}{\partial x_K}$, $\quad f_j(x) = \frac{\partial f}{\partial X_j}$

For similar definitions see Berndt and Christensen (1973).

31. For instance, given $\beta_{ij}=\alpha_i\rho_j$, depending on the variables taken by i and j different types of separability conditions can be specified. Accordingly, the separability conditions are specified in sections, 2.C.3, 2.C.4, 2.C.6.1, 2.C.6.2. It is also important to note that the separability of L, K, E from R and NR does not imply the separability of R and NR from L, K, E since empirically, they provide different results. With respect to homothetic separability the former statement implies fewer constraints than the latter statement.

32. See Berndt and Christensen (1973) p. 404.

33. See Berndt and Christensen (1973), pp. 406-407. They have proved this result.

34. Since one of the share equations is deleted in estimating the share equations there are four effective constraints for four equations.

35. See Fuss and McFadden (1978) volume 2, pp. 61-62.

In the present formulation: Let Q=f(L, K, E, R, NR) be the non-homothetic production function, this will be weakly separable if

$$Q=f(h(L, K, E), R, NR).$$

If g is homothetic in L, K, E then the dual cost function will be weakly separable . That is,

$$C=g(h(P_L, P_K, P_E), P_R, P_{NR}, Q)$$

hence the conditions $d_{iQ}=\rho_Q\alpha_i$ (i=L, K, E) and $\beta_{ij}=\rho_j\alpha_i$

(i=L, K, E; j=R, NR) follow.

36. Similar restrictions follow (as in footnote 35), for similarly specified cost functions as in (48).

Chapter 3. Factors of Production: Measurement Problems

Many measurement problems are encountered in the investigation of the relations between economic variables. The variables in production relationships--namely, capital, labour, energy, renewable and non-renewable resources--are not simple quantities; rather, they are aggregates consisting of many variables each of which must have a consistent measure. Because each aggregate variable consists of many sub-components the following problems arise: (a) How to aggregate the variables? (b) How should they be measured and why should one measure be preferred to another?

For each input we have to calculate a series of aggregate input quantities (that is, a real measure of the input) and a corresponding series of its prices. The aggregation problem is common to each and every input. Therefore, before describing the measurement of input variables in detail we briefly focus our attention on the aggregation problem in general.

3.A Aggregation

The many components which comprise any given factor input have substantive differences in the number and type of attributes. This non-homogeneity and non-perfect substitutability is the basis of the aggregation problem; that is, how does one add together the many varied

components in a consistent fashion? With energy, for example, the various fuels and electricity are less than perfectly substitutable either in production or consumption (Berndt 1978). Similar arguments apply to other inputs as well. In the case of labour, for example, production and non-production workers are not perfectly substitutable. Similar problems arise with capital.

Indexing is a means for aggregating components of any economic indicator. However, there are many different methods of indexing aggregate inputs all of which have different characteristics.[1] Two important and desirable characteristics of an index aggregator are, firstly, that the aggregate formula should be as general as possible in that it should be flexible and should not impose any *a priori* restriction on the substitution possibilities among components. Secondly, the index formula should be justified from the point of view of economic theory and should have economic interpretations.[2] The aggregate index should be a consistent one and should have proper sequencing. If there is a change in any economic component of the aggregate input variable, it should be reflected in the aggregate index. For example, if there is a change in the price of fuel oil, one of the aggregate energy components, the change should be reflected consistently in the aggregate price index for energy so that the proper economic impact of such a change can be realized (e.g. the effect on own demand for aggregate energy and possible effects on other input demands).

One method of constructing an index of quantity or price is to use a simple weighted average of sub-components. Such an index, however, will be accurate only if the components are perfect substitutes. Berndt (1978) has shown that in the case of energy aggregation, simple physical measures such as total BTU's are unsatisfactory. The reason for this is three-fold: (1) energy components are not homogeneous, (2) they are not perfect substitutes and (3) choice among fuels is affected by prices, preferences and technology.[3]

Fisher (1922) pioneered a general indexing method which does not suffer from the above disadvantages. It was later extended by Diewert (1975, 1976, 1978) who emphasized the use of discrete Divisia indexes. This method is used to aggregate input variables in this study.

The Divisia index for the aggregate input quantity is composed of n components and is defined as follows:

$$\log(q_t)-\log(q_{t-1})=\sum_i w_{it}(\log(q_{it})-\log(q_{it-1})) \qquad (1)$$

where $w_{it}=(s_{it}+s_{it-1})/2$, is an average of the observations' expenditure share in the last two periods with $s_{it}=p_{it}q_{it}/(\sum_i p_{it}q_{it})$. For the corresponding price index p's replace the q's.

In terms of energy aggregation, the heuristic interpretation of the discrete Divisia index (1) above has been given by Berndt (1978), p. 247 as

> 'the percentage (logarithmic) change in the aggregate energy quantity index is a weighted average of the percentage (logarithmic) quantity changes of the component energy types, where the weights are the time-varying 'chained' mean expenditures or cost shares'

Hulten (1973) and Diewert (1976) have shown that the Divisia index has a number of desirable properties as an aggregation procedure. Diewert (1976) has shown that the Divisia index allows variable substitution without imposing any *a priori* restriction on the substitution parameters. It has also been shown by Diewert (1975) that the aggregator function for which the Divisia index is exact is the translog function. May and Denny, (1979) have demonstrated that the Tornqvist index[4] is an exact discrete approximation to a continuous translog function.

There are also other general index number formulae such as Fisher's ideal index, Vertia, Implicit Tornqvist, chained Laspeyres and chained Paasche indexes.[5] Diewert (1978) has shown that these formulae do not always differ significantly in actual calculation. Fisher's ideal index which is a geometric mean of a Paasche and of a Laspeyres' quantity index, is a superlative index and is exact for the homogeneous quadratic transformation function (Diewert, 1974).[6]

It follows from the above discussion that in aggregation we may apply any one of these general index

number formulae. However, the Divisia index is the preferred choice because of its convenient computational features as well as its consistency with respect to the translog function. Moreover, the added advantage with the Divisia index is that

> 'continuous shifting of the price weights can take place in such a way as to minimize distortion in aggregate index while maintaining the integrity of the measurement of quality change'

(Berndt, 1978).

The following sections outline the explicit means and methods of incorporating the above considerations into actual data construction.

3.A.1 Capital

Of all the factors of production, the measurement of capital is known to be the most controversial.[7] The appropriate measure of capital would be a flow measure of 'capital services' since output is measured as units of the good per unit time. Capital services, rather than a weighted average of machines used, is an appropriate measure of capital, because the same number of machines may be used more intensively or less intensively. In addition, different vintages of machines may provide different levels of capital services due to technological differences.[8] However, it is difficult to obtain data on capital services. The usual procedure is first to measure capital value and

deflate it by a price index to obtain a measure of the level of capital stock. This level is then adjusted by a utilization rate for use as a measure of capital services.

For this study the net capital stock Kit (i-th type of capital) in period t is computed by using the perpetual inventory method.[9]

The expression for K_{it} is given by

$$K_{it}=I_{it}+(1-\delta_i)K_{it-1} \qquad (2)$$

where K_{it} is the net stock of the i-th type of capital good at time t, I_{it} is investment at time t, δ_i is the rate of depreciation of i-th type of capital good, K_{it-1} is capital stock in the previous time period.

3.A.2 Rental Price of Capital

The most commonly used method of calculating the rental price of capital P_K was pioneered by Hall and Jorgenson (1967). Following their method

$$P_K=P_S(r+\delta) \quad (1-u_t z)/(1-u_t) \qquad (3)$$

where

P_S=price of capital stock

r=an interest rate

δ=depreciation rate

u_t=effective tax rate, measured by corporation income tax/corporation profits before taxes

z=the present value of the depreciation allowances available from a dollar's investment in a particular type of capital-structures or equipment.

z is obtained as follows:

$$z= 1/T/(R+1/T) \quad 1-\bar{e}^{(R+1/T)T} \qquad (4)$$

where R=the rate of discount, and T=the economic life of the asset.

The use of an appropriate interest rate r is an important consideration. An interest rate can be either nominal or real. A real rate of interest is one which abstracts from the inflation factor. Inflation being a transfer, is an external factor which does not reflect the real economic cost. A real rate of return, being adjusted for inflation, reflects the actual economic cost. Therefore, the use of a real interest rate or a real rate of return is to be preferred to use of a nominal interest rate. Some authors (see Gaudet et al., 1976) use interest rate $r = (1-u)i$, where i is the nominal interest rate, u is the effective tax rate as defined above.

For calculating the rental price of capital for the present study, we have followed the neoclassical theory and have followed Jorgenson and Hall's methodology as was done by Berndt, (1979). This procedure involves the use of a real rate of interest. The formulae used by Berndt are described in Appendix 1.

3.A.3 Labour

There are different measures of labour input such as the number of workers, man-hours paid and man-hours worked. Among these three measures man-hours worked is preferred

because this measure is the standard working unit and the associated compensation takes into account fringe benefits, bonus, and other supplementary income as well as employment tax credits (ETC). It is important to use a measure accurate enough to reflect all forms of compensation affecting the value of labour.

Man-hours worked is a better measure of labour input (and provides a better measure of labour cost) than the number of workers because in distinguishing between part-time and full-time workers and accounting for overtime it reflects better the flow of labour services. Man-hours paid is a better measure than the number of workers but is not better than man-hours worked.[10] For man-hours paid the fringe and supplementary benefits are not included on the basis of the standard working unit (hours worked). Consequently, the wage rates determined from man-hours worked data exceeds that determined on a man-hours paid basis and so more adequately reflects the value (cost) of labour input.

Sato (1970) has demonstrated that aggregate labour input in the aggregate production function should be wage-corrected total man-hours if the real hourly wage rate varies with the number of hours worked. That is,

$$w/p=f(h) \qquad (5)$$

where w=wage rate

p=price of output

w/p=real wage rate

h=number of hours worked.

For theoretical reasons labour input should be measured as man-hours worked since according to marginal productivity theory, the marginal product of labour (MPL) is given by

$$MPL=w/p \qquad (6)$$

assuming perfect competition in the factor and product markets. From (5) and (6) it follows that

$MPL=w/p=f(h)$, a function of man-hours worked.

In this study man-hours worked is used as the measure of labour input.

3.A.4 Quality Adjustment of Labour

Of all the characteristics of the labour force such as education, skill, age, and sex, education has been found empirically to be the major contributing factor to the growth of labour input.[11] According to Denison (1967), 40 to 50 percent to the growth of the total labour input of the U.S. economy in the post-war period can be attributed to greater educational attainment, while according to Griliches (1968) the contribution was about two-thirds to the growth of total labour input in the United States manufacturing sector for the period 1947-1960. However, the contribution of other factors such as technological progress, learning by doing etc. should also be taken into consideration in the growth rate of total labour input.

If a consistent labour input measure is to be used a quality adjustment may be necessary. This adjustment can be

done by adjusting the man-hours worked data by an appropriately constructed educational attainment index (EAI).[12] For the total manufacturing sector all necessary data for constructing an EAI are available. However, not all these data are available for specific two-digit level industries. The constructed EAI which is appropriate for the total manufacturing sector may not be appropriate for specific two-digit level industries because of the non-homogeneity and diversity of their workers. For example, tobacco manufacturing is very different from metal fabricating. Consequently, no quality adjustment is made to the labour data for the two-digit level industries in this study. However, this adjustment has been made for the total manufacturing sector.[13]

Another problem that arises in measuring labour compensation is to obtain data for supplementary labour income. As mentioned before supplementary labour income is needed to obtain the total labour compensation to adequately reflect the cost of labour. In this study we have used the fringe benefits data as available from a specific source[14] as a means of incorporating supplementary labour income.

Finally, wage rate (cost of labour) per man-hour worked is obtained as a ratio of total labour compensation to total man-hour worked. A detailed description of data construction is provided in Appendix 1.

3.A.4 Energy

Energy resources in Canada consist of the following major components and sub-components of non-renewable resources.[15]

(1)Fuel oil: the sub-components are

(a) Kerosene

(b) Diesel oil

(c) Light fuel oil

(d) Heavy fuel oil

(2) Natural gas

(3) Electricity

(4) Motor gasoline

(5) LPG: Liquified petroleum gas

(6) Coal: the sub-components are

(a) Lignite

(b) Sub-Bituminous

(c) Imported Bituminous

(d) Bituminous

(e) Anthracite

(f) Coke

Total energy input is an aggregation of all these components. We need a series of the aggregate quantities of energy (QE) and a corresponding series of prices for the aggregate (PE). PE and QE can be obtained by constructing appropriate index numbers. The ideal index for this purpose is obtained by the Divisia index method.

Since the energy components and sub-components are in various natural units such as gallons of oil, tons of coal, millions of cubic feet of natural gas (mcf), Kw-hour of electricity etc., the task is to convert them into a common unit before constructing an index. There are two steps in making the most suitable conversion of different energy sources into a common unit. The first step is to transform the natural units into equivalent input BTUs. Then , since there are substantial differences in the efficiency units of these components and sub-components, it is desirable to transform the input BTUs into output BTUs. These steps were followed in constructing the aggregate energy price (PE) and quantity (QE) measures.[16]

In measuring aggregate energy input one of the practical problems is to obtain own generation of electricity data for the two-digit level industries. Own generation of electricity is obtained by taking the difference between the available total consumption of electricity and the purchased amount of electricity. However, total consumption data were not available for all two-digit level industries. Approximate allocation and adjustments have been made in obtaining estimates of own generation of electricity. (Details are given in the Appendix 1). Another problem is the unavailability of energy data for 1961. We have estimated these data by extrapolation using a regression technique (as discussed in Appendix 1).

3.A.5 Resources

Materials (M) in the KLEM model can be considered as consisting of basic resources--renewable, non-renewable and other (manufactured) material inputs.

Resources refers to material inputs other than energy inputs and finished intermediate products. As defined here, resources encompasses principally 'raw' materials which may be either in the primary or in processed form and useable for further manufacturing production. For example, grains as defined by Statistics Canada (15-509) consist of unmilled wheat, barley, oats, rye, corn and other grains which are in the primary form. On the other hand, copper and copper alloy products consist of copper and copper alloys in the primary form and also copper products (castings, rolled and extruded items). Therefore, our resources are not necessarily purely primary products but may have undergone some preliminery processing.

Other materials are inputs that have been processed further than those identified as renewable and non-renewable resources which are basically raw materials. These other materials have been excluded from our five input model.

We define our aggregate resource as consisting of the following components of the Canadian Input-Output Table SC (15-509E); the selection of resources being according to our definition of natural resources. In identifying resources we have followed the definition of the individual components as provided in the Input-Output Table (SC (15-509E) p. 45)

and also the breakdown provided there (SC (15-509E) pp. 38-44).

3.A.5.1 Renewable Resources

(1) Grains

(2) Live animals

(3) Other agricultural products

(4) Forestry products

(5) Fish landings

(6) Hunting and trapping products

(7) Meat products

(8) Dairy products

(9) Fish products

(10) Lumber and timber

(11) Pulp

(12) Veneer and plywood.

3.A.5.2 Non-renewable Resources

(1) Iron ores and concentrates

(2) Other metal ores and concentrates

(3) Non-metallic minerals

(4) Copper and copper alloy products

(5) Other non-ferrous metal products

(6) Nickel products

(7) Other non-metallic mineral products

(8) Crude mineral oils

(9) Aluminum products

(10) Iron and steel products.

An aggregation problem arises given the different types of renewable and non-renable resource components. One method of aggregation would be to follow the same procedure as mentioned above for energy (i.e. Divisia index aggregation). However, a common unit and/or a real measure is required to apply the Divisia index for aggregation. In the case of energy there is a common unit across the various types, but for resoures there is not. However, a real (constant price) measure of resource input is available from the Canadian input-output table using either 1961 or 1971 as the base year.[17] As Statistics Canada explains (see SC 13-509E p. 17).

> 'There is no meaningful way to combine tons of steel and dozens of oranges, for example. The only workable solution to this dilemma is to fix values for these quantities in terms of their prices at some point in time, the base year. Thus the dollar value of a quantity of oranges is additive to the dollar value of a quantity of steel. If all quantities are expressed in terms of their base year prices, the constant values for each commodity will be proportional to its quantites in different years, yet commodities of diverse characteristics will remain additive, and the construction of a set of accounts summarizing manifold transactions is possible.'

Aggregate prices and quantity indexes for renewable and non-renewable resources are obtained by the Divisia aggregation procedure using the real measures available from the input-output table based on 1971 constant prices. A detail description of the construction of aggregate quantities (QR, renewable, QNR, non-renewable) and prices (PR, renewable, PNR, non-renewable) is given in Appendix 1.

3.B Output

3.B.1 Output Quantity

Output should be measured in terms of physical quantities.[18] But in aggregate production studies data in physical quantites are usually not available. Therefore, output is measured either as real value added or as real gross output. Since the value-added specification has been called into question (Berndt and Wood, 1975)[19], recent studies with energy and materials as well as labour and capital inputs use real gross output as the output measure. The present study will also use real gross output (defined to exclude other materials) as the output measure appropriately defined.

The real gross output is obtained by deflating current gross output by the appropriate output price index. The Canadian production studies use the appropriate industry selling price index to deflate current value of gross output. This study will also use the same appropriate industry selling price index.

3.B.2 Total Cost

Total cost is the sum of the costs of all inputs included in the specification of the production or the cost function. This is defined as

$TC=\sum_i p_i x_i$ where p =price of i-th input and x_i=quantity of i-th input.

It can be seen that there is a difference between total cost and total output. Total cost is an aggregate of current values while total output is a real measure.

In order to be consistent with renewable and non-renewable resource data as obtained from the input-output table with 1971 as the base year, we also choose 1971 as the base year for other variables such as capital, labour and energy.

Footnotes to Chapter 3

1. Alternatives include a simple (unweighted) index, a weighted index, Laspeyre's index, Paasche index, Fisher ideal index, Tornqvist index or the Divisia index, Vertia index. For a discussion of these indices see Diewert (1976, 1978) and Berndt (1978).

2. See Berndt (1978). Also see Diewert (1978), p.895 and other references cited there.

3. See Berndt (1978), p.269.

4. Tornqvist index is the same as the discrete form of the Divisia index. See May and Denny (1979), p. 773.

5. See Diewert (1978) pp. 894-895. Diewert has shown the necessity of using the "chain" principle in the cases of Paasche and Laspeyre's indexes. In the cases of either of these index formula, derivatives coincide only to the first order, which in turn implies Cobb-Douglas aggregation. Therefore, it has been suggested by Diewert (1978) that government agencies should use chained rather than fixed base indexes in order to deflate expenditures into constant dollar quantities.

6. The term superlative index refers to an ideal index formula having the desirable properties of an index aggregator. This has also been demonstrated by Danielson (1975), p. 184.

7. See Nadiri (1970) pp. 1144-1146.

8. See Varian (1978), p. 119.

9. See Statistics Canada Catalogue number 13-522, for detailed discussion on methodology concerning the perpetual inventory method.

10. The main problem with the number of workers is that this may not take into account of part-time and over time workers. Statistics Canada, catalogue number, 14-201 distinguish between "man-hours worked", and "man-hours paid", as follows:

> "man-hours worked are the sum of man-hours spent at the place of employment by persons employed and therefore, differ from a measure of man-hours paid by excluding time used on vacation, holiday, illness, accident etc.

11. See Nadiri (1970).

12. For the construction of educational attainment index (EAI) see Berndt (1979).

13. These data were kindly provided by Professor Berndt formerly of the University of British Columbia (now at Massachusetts Institute of Technology).

14. These data were published by "The Thorne Group Limited, Management Consultant."

15. Other fuels represent a small (minimal) part of energy outlays for which quantities are not reported.

16. We have followed the same methodology used by McRae and Webster (1978).

17. Since most of the other data are also indexed with 1971 as the base year, we have chosen 1971 as base data.

18. For example, ton miles in the case of transportation, kg per hector in the case of agricultural output.

19. See Berndt and Wood (1975) p. 266. Also see Denny and May (1977).

Chapter 4. Estimation and Hypothesis Testing

In this chapter we discuss the problem of estimating the translog parameters and the methods for testing hypotheses concerning homotheticity and separability. Estimation problems and their solution are discussed in section A while the tests of hypotheses are discussed in section B.

4.A Estimation

The models developed and specified in Chapter 2.B, are to be empirically estimated. The empirical implementation requires that the cost and share equations be imbedded in a stochastic framework. The stochastic specification of the selected translog cost function is

$$
\begin{aligned}
\text{LogC} = {} & \log\alpha_L + \alpha \log(P_L/P_{NR}) + \alpha_K \log(P_K/P_{NR}) + \alpha_E \log(P_E/P_{NR}) \\
& + \alpha_R \log(P_R/P_{NR}) + \log(P_{NR}) + \tfrac{1}{2}\beta_{LL}(\log(P_L/P_{NR}))^2 + \\
& \beta_{LK}\log(P_L/P_{NR})\log(P_K/P_{NR}) + \beta_{LE}\log(P_L/P_{NR}) \\
& \log(P_E/P_{NR}) + \beta_{LR}\log(P_L/P_{NR})\log(P_R/P_{NR}) + \tfrac{1}{2}\beta_{KK} \\
& (\log(P_K/P_{NR}))^2 + \beta_{KE}\log(P_K/P_{NR})\log(P_E/P_{NR}) + \\
& \beta_{KR}\log(P_K/P_{NR})\log(P_R/P_{NR}) + \tfrac{1}{2}\beta_{EE}(\log(P_E/P_{NR}))^2 \\
& + \beta_{ER}\log(P_E/P_{NR})\log(P_R/P_{NR}) + \tfrac{1}{2}\beta_{RR}(\log(P_R/P_{NR}))^2 \\
& + \alpha_Q\log(Q) + \tfrac{1}{2}\beta_{QQ}(\log(Q))^2 + d_{LQ}\log(Q)\log(P_L/P_{NR}) \\
& + d_{KQ}\log(Q)\log(P_K/P_{NR}) + d_{EQ}\log(Q)\log(P_E/P_{NR}) \\
& + d_{RQ}\log(Q)\log(P_R/P_{NR}) + u_C
\end{aligned}
\qquad (1)
$$

where u_C is the disturbance term.

Imposing the restriction $\sum_j \beta_{ij}=0$ and substituting for $\beta_{ii}=-\sum_{j\neq i}\beta_{ij}$, we obtain the cost share equations with stochastic specification as follows:

$$
\begin{aligned}
S_L &= \alpha_L + \beta_{LK}\log(P_K/P_L) + \beta_{LE}\log(P_E/P_L) + \beta_{LR}\log(P_R/P_L) + \\
&\quad \beta_{LNR}\log(P_{NR}/P_L) + d_{LQ}\log(Q) + u_L \\
S_K &= \alpha_K + \beta_{LK}\log(P_L/P_K) + \beta_{KE}\log(P_E/P_K) + \beta_{KR}\log(P_R/P_K) + \\
&\quad \beta_{KNR}\log(P_{NR}/P_K) + d_{KQ}\log(Q) + u_K \\
S_E &= \alpha_E + \beta_{LE}\log(P_L/P_E) + \beta_{KE}\log(P_K/P_E) + \beta_{ER}\log(P_R/P_E) + \\
&\quad \beta_{ENR}\log(P_{NR}/P_E) + d_{EQ}\log(Q) + u_E \\
S_R &= \alpha_R + \beta_{LR}\log(P_L/P_R) + \beta_{KR}\log(P_K/P_R) + \beta_{ER}\log(P_E/P_R) + \\
&\quad \beta_{ENR}\log(P_{NR}/P_R) + d_{RQ}\log(Q) + u_R \\
S_{NR} &= \alpha_{NR} + \beta_{LNR}\log(P_L/P_{NR}) + \beta_{KNR}\log(P_K/P_{NR}) + \\
&\quad \beta_{ENR}\log(P_E/P_{NR}) + \beta_{RNR}\log(P_R/P_{NR}) + d_{NRQ}\log(Q) + u_{NR}
\end{aligned}
\tag{2}
$$

where u_L, u_K, u_E, u_R, u_{NR} are the disturbances.[1]

The problems of multicollinearity and autocorrelation are usually encountered in the estimation of such a system. However , with homogeneity restrictions the derived factor demand or cost share equations can be estimated as functions of the ratios of inputs or input prices which reduces collinearity.[2] Yet, if there are a large number of factors involved, the ratio variables also tend to be collinear. Since multicollinearity substantially restricts the power of any test,[3] the results of a multi-input study must be interpreted accordingly.

In the estimation of a system of equations such as (1) and (2) combined or (2) alone, one also encounters other

types of issues; namely, (1) the error structures which favour joint estimation and (2) invariance of estimates as to deletion of one of the equations. We discuss each of these questions below.

4.A.1 The Adding Up Problem in the Estimation of Share Equations

Since the adding up constraint of the share equations ($\sum_i S_i=1$) implies that $\sum_i u_i=0$, this in turn implies singularity of the variance-covariance matrix of the error structure, and one of the equations must be deleted. The basis for this can be shown as follows.

In order to write the system of equations in (2) as standard individual regression equations we denote

$$Y_L=S_L,\ Y_K=S_K,\ Y_E=S_E,\ Y_R=S_R,\ Y_{NR}=S_{NR}$$

and

$$X_L=(X_0\ X_{KL}\ X_{EL}\ X_{RL}\ X_{NRL}\ X_Q)$$
$$X_K=(X_0\ X_{LK}\ X_{EK}\ X_{RK}\ X_{NRK}\ X_Q)$$
$$X_E=(X_0\ X_{LE}\ X_{KE}\ X_{RE}\ X_{NRE}\ X_Q)$$
$$X_R=(X_0\ X_{LR}\ X_{KR}\ X_{ER}\ X_{NRR}\ X_Q)$$
$$X_{NR}=(X_0\ X_{LNR}\ X_{KNR}\ X_{ENR}\ X_{RNR}\ X_Q) \qquad (3)$$

where

X_0=a vector of unit elements

$X_{jL}=\log(P_j/P_L)$ j=K, E, R, NR

$X_{jK}=\log(P_j/P_K)$ j=L, E, R, NR

$X_{jE}=\log(P_j/P_E)$ j=L, K, R, NR

$X_{jR}=\log(P_j/P_R)$ j=L, K, E, NR

$X_{jNR}=\log(P_j/P_{NR})$ j=L, K, E, R

$X_Q=\log(Q)$.

or

$X_{Lj}=-\log(P_L/P_j)$

$X_{Kj}=-\log(P_K/P_j)$

$X_{Ej}=-\log(P_E/P_j)$

$X_{Rj}=-\log(p_R/P_j)$

$X_{NRj}=-\log(P_{NR}/P_j)$ and

$$\beta_L=\begin{bmatrix}\alpha_L\\ \beta_{LK}\\ \beta_{LE}\\ \beta_{LR}\\ \beta_{LNR}\\ d_{LQ}\end{bmatrix}\quad \beta_K=\begin{bmatrix}\alpha_K\\ \beta_{LK}\\ \beta_{KE}\\ \beta_{KR}\\ \beta_{KNR}\\ d_{KQ}\end{bmatrix}\quad \beta_E=\begin{bmatrix}\alpha_E\\ \beta_{LE}\\ \beta_{KE}\\ \beta_{ER}\\ \beta_{ENR}\\ d_{EQ}\end{bmatrix}\quad \beta_R=\begin{bmatrix}\alpha_R\\ \beta_{LR}\\ \beta_{KR}\\ \beta_{ER}\\ \beta_{RNR}\\ d_{RQ}\end{bmatrix}\quad \beta_{NR}=\begin{bmatrix}\alpha_{NR}\\ \beta_{LNR}\\ \beta_{KNR}\\ \beta_{ENR}\\ \beta_{RNR}\\ d_{NRQ}\end{bmatrix}$$

and the system of equations can be written as

$$y_L=X_L\beta_L+u_L$$
$$y_K=X_K\beta_K+u_K$$
$$y_E=X_E\beta_E+u_E$$
$$y_R=X_R\beta_R+u_R$$
$$y_{NR}=X_{NR}\beta_{NR}+u_{NR} \qquad (4)$$

or

$$y_i=X_i\beta_i+u_i \quad i=L,\ K,\ E,\ R,\ NR \qquad (5)$$

Again in matrix notation (5) can be written as

$$\begin{bmatrix}y_L\\ y_K\\ y_E\\ y_R\\ y_{NR}\end{bmatrix}=\begin{bmatrix}X_L & 0 & 0 & 0 & 0\\ 0 & X_K & 0 & 0 & 0\\ 0 & 0 & X_E & 0 & 0\\ 0 & 0 & 0 & X_R & 0\\ 0 & 0 & 0 & 0 & X_{NR}\end{bmatrix}\begin{bmatrix}\beta_L\\ \beta_K\\ \beta_E\\ \beta_R\\ \beta_{NR}\end{bmatrix}+\begin{bmatrix}u_L\\ u_K\\ u_E\\ u_R\\ u_{NR}\end{bmatrix} \qquad (6)$$

Further let L=1, K=2, E=3, R=4, NR=5

$X_L=(X_0\ X_{j1}\ X_Q)$ j=2, 3, 4, 5

$X_K=(X_0\ X_{j2}\ X_Q)$ j=1, 3, 4, 5

$X_E=(X_0\ X_{j3}\ X_Q)$ j=1, 2, 4, 5

$X_R=(X_0\ X_{j4}\ X_Q)$ j=1, 2, 3, 5

$X_{NR}=(X_0\ X_{j5}\ X_Q)$ j=1, 2, 3, 4

Deleting the fifth equation in (6) and imposing the symmetry restriction ($\beta_{ij}=\beta_{ji}$) the system of remaining four equations can be written as

$$Y=X\beta+U \qquad (7)$$

where

$$Y=\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix}$$

a 4n by 1 vector of dependent variables, where n is the size of the sample;

$$X=\begin{bmatrix} X_0 & 0 & 0 & 0 & X_{21} & X_{31} & X_{41} & X_{51} & 0 & 0 & 0 & 0 & 0 & 0 & X_Q & 0 & 0 & 0 \\ 0 & X_0 & 0 & 0 & X_{12} & 0 & 0 & X_{32} & X_{42} & X_{52} & 0 & 0 & 0 & 0 & 0 & X_Q & 0 & 0 \\ 0 & 0 & X_0 & 0 & 0 & X_{13} & 0 & 0 & X_{23} & 0 & 0 & X_{43} & X_{53} & 0 & 0 & 0 & X_Q & 0 \\ 0 & 0 & 0 & X_0 & 0 & 0 & X_{14} & 0 & 0 & X_{24} & 0 & X_{34} & 0 & X_{54} & 0 & 0 & 0 & 0 & X_Q \end{bmatrix}$$

a 4n by k matrix of observations;

$\beta'=(\alpha_1\ \alpha_2\ \alpha_3\ \alpha_4\ \beta_{12}\ \beta_{13}\ \beta_{14}\ \beta_{15}\ \beta_{23}\ \beta_{24}\beta_{25}\ \beta_{34}\ \beta_{35}\ \beta_{45}\ d_{1Q}d_{2Q}\ d_{3Q}d_{4Q})$; and

$$U=\begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix}$$

a 4n by 1 vector of disturbances.

Also

$X_{j1}=\log(P_j/P_1)$ j=2, 3, 4, 5

$X_{j2}=\log(P_j/P_2)$ j=1, 3, 4, 5

$X_{j3}=\log(P_j/P_3)$ j=1, 2, 4, 5

$X_{j4}=\log(P_j/P_4)$ j=1, 2, 3, 5

and

$X_{1j}=-\log(P_1/P_j)$ j=2, 3, 4, 5

$X_{2j}=-\log(P_2/P_j)$ j=1, 3, 4, 5

$X_{3j}=-\log(P_3/P_j)$ j=1, 2, 4, 5

$X_{4j}=-\log(P_4/P_j)$ j=1, 2, 3, 5

It is assumed that the u 's in (6) are normally distributed with mean $E(u_{it})=0$, i=1,2,-- n and that the variance-covariance matrix as given by $E(u_{it}u'_{it})= \sigma_{ii}I_n$, for i=1, 2, --- n where I_n is an identity matrix of order n by n, and the explanatory variables are non-stochastic. This means that each equation is expected to satisfy the assumptions of a standard linear regression model. However, the possibility that the regression disturbances in different equations are mutually correlated cannot be ruled out.

In the present case, the dependent and independent variables of the system represent a given firm or industry

production structure. As such, any of the firm's reactions to changes in any of the prices (the independent variables) will affect the cost shares (the dependent variables) across all equations and hence the disturbance terms. Therefore, it is quite likely that the equations will be related through the disturbance structure. For these reasons, the covariance of the disturbances of the i-th and the j-th equation are expected to be non-zero.

A system such as the one above whose equations are only related through the disturbance structure is called a system of seemingly unrelated regressions.[4] The covariance structure for such a system is defined by

$$E(u_{it}u_{jt})=\sigma_{ij}I_n \text{ for all } i,j=L,\ K,\ E,\ R,\ NR \qquad (8)$$

where I_n is an identity matrix of order n by n.

Under all of the above assumptions, the variance-covariance matrix for U can be written as

$$\Sigma=\Sigma_c \otimes I$$

where Σ_c is a positive definite variance-covariance matrix of the n-th order with elements σ_{ij},

$$\Sigma_c = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \text{-----} & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} & \text{----} & \sigma_{2n} \\ & \cdot\ \cdot & & \\ \sigma_{n1} & \sigma_{n2} & \text{-----} & \sigma_{nn} \end{bmatrix} \qquad (9)$$

It will be assumed that U is distributed as multivariate normal with mean vector zero and variance-covariance matrix Σ; that is

$U \sim N(0, \Sigma)$

Efficient estimation can be obtained by applying Aitken's generalized least squares (GLS) to (7). The GLS estimator is given as

$$\hat{\beta}_{GLS} = (X^1\Sigma^{-1}X)^{-1}X^1\Sigma^{-1}Y \qquad . \qquad (10)$$

and is a best linear unbiased estimator. In the context of seemingly unrelated regressions, the estimator is

$$\begin{bmatrix} \sigma^{11}\, x_1^1 x_1 & \sigma^{12} x_1^1 x_2 & \sigma^{1n} x_1^1 x_n \\ \sigma^{21}\, x_2^1 x_1 & \sigma^{22} x_2^1 x_2 & \sigma^{2n} x_1^1 x_n \\ \sigma^{n1}\, x_n^1 x_1 & \sigma^{n2} x_n^1 x_2 & \sigma^{nn} x_n^1 x_n \end{bmatrix}^{-1} \begin{bmatrix} \sum_j \sigma^{1j} x_1^1 x_j \\ \sum_j \sigma^{2j} x_2^1 x_j \\ \sum_j \sigma^{nj} x_n^1 x_j \end{bmatrix} \qquad (11)$$

where σ^{ij} represents the (i, j)th element of the inverse of the matrix Σ_c in (9).

The variance-covariance matrix of the estimator is given by

$$E(\hat{\beta}-\beta)(\hat{\beta}-\beta)^1 = (X^1\Sigma^{-1}X)^{-1} \qquad (12)$$

Since Σ_c is unknown, a feasible GLS (generalized least squares) estimator must be devised. Zellner (1962) proposed that in the first stage ordinary least squares be applied to each equation in (5) to obtain the residuals which are then to be used to obtain estimators of the elements of Σ_c to form $\hat{\Sigma}_c$.[5] The feasible GLS estimator is then defined by $\hat{\beta} = (X^1\hat{\Sigma}^{-1}X)^{-1}\ (X^1\hat{\Sigma}^{-1}\ Y)$. However, the estimates obtained by

applying Zellner's two-stage technique depend on which equation in the system is deleted.[6] This question is discussed next.

4.A.2 Invariance of Estimates Due to Deletion of One Equation

Since Zellner's two-stage procedure is not invariant with respect to the deletion of one of the equations it is desirable to find an estimation technique which is invariant with respect to the deletion of any equation. Maximum likelihood estimation (MLE) and iterative Zellner estimation (IZE) are examples of such techniques. The latter technique is the one which uses Zellner's two-stage estimates of the regression coefficients for calculating a new set of residuals leading to a new estimate of Σ_c which can be used for obtaining new estimates of the regression coefficients and so on (see Kmenta and Gilbert, 1968, p. 1184).

Most of the known statistical properties of these estimators are asymptotic. MLE, for example, are consistent, asymptotically efficient and asymptotically normally distributed. However, estimates based on a finite small sample may not satisfy these large sample properties. The small sample properties are usually investigated by Monte Carlo experiments. From a series of such Monte Carlo experiments, Kmenta and Gilbert (1968) have shown that the iterative Zellner estimates (IZE) and MLE are identical. Ruble (1968) has also shown that the IZE and MLE are computationally equivalent. These IZE estimates are,

therefore, equivalent to the MLE estimates and are thus independent of the equation deleted as well as having all the desirable large sample properties of ML estimators.

An alternative to IZE is Malinvaud's (1970) minimum distance estimator (MDE). Invariance of parameter estimates is assured if the MDE is applied and iterated to converge on estimates of both the parameters and the variance-covariance matrix.[7] This is known as the iterative minimum distance estimator (IMDE) technique. Berndt et al. (1974) have shown that if the errors are normally distributed then this provides maximum likelihood estimates for multivariate regression models. These estimates are also asymptotically efficient. The application of either IZE or IMDE, therefore, solves the problem of invariance.

Since the cost function involves many parameters (more than the share equations) it is required to have a large number of observations if one is to apply ordinary least squares to the cost function in order to estimate the residuals. On the other hand, share equations can be estimated with fewer observations. As to the single equation estimation, Guilkey and Lovell (1980), using the CES technology , have found the single equation estimating model to perform marginally better, at far less cost, than the system of equations model when the underlying technology is not translog. Whether these results hold for the translog technology is yet to be determined. However, for the present study the number of observations is less than

the number of parameters. Therefore, the estimation of the cost function alone (that is, single equation) is automatically ruled out.

It is possible to estimate the cost function and the share equations jointly and in this case sufficient degrees of freedom can be obtained when cross equation constraints are imposed.[8] Inclusion of the cost function yields estimates of all the parameters including α_0, α_Q, β_{QQ} (equation 1) which are necessary for the calculation of the scale elasticity[9], as well as model simulation. Because of multicollinearity it was not possible to estimate the entire system. Therefore, the present study will be confined to the estimation of the system of share equations only. This will not affect the objectives of the study.

4.B Hypothesis Testing

For testing the separability hypotheses outlined in Chapter 2.C or testing any restriction on the parameters of the translog model, we can apply the likelihood ratio (LR) test. The LR is defined as

$$\lambda = \operatorname*{Max}_{\omega} L / \operatorname*{Max}_{\Omega} L \qquad (13)$$

where λ =likelihood ratio, L is the likelihood function and ω implies a constrained model and Ω implies an unconstrained model.

Assuming that the disturbances are normally distributed with mean vector zero and variance-covariance matrix Σ, (13) can be shown to be

$$\lambda = \frac{|\hat{\Sigma}\omega|^{-T/2}}{|\hat{\Sigma}\Omega|^{-T/2}} \qquad (14)$$

and taking the logarithm of both sides of (14) and multiplying by -2, we obtain

$$-2\log(\lambda)=T(\log|\hat{\Sigma}\omega|-\log|\hat{\Sigma}\Omega|) \qquad (15)$$

Under the null hypothesis the test statistic $-2\log(\lambda)$ is asymptotically distributed as chi-squared, χ^2, with the number of degrees of freedom equal to the number of restrictions to be imposed.[10]

The iterative minimum distance (IMD) estimator as available in the TSP package (known as LSQ, denoting non-linear least squares) provides the estimated value of the log of the likelihood function. The LSQ program will be used to estimate the models and to test the hypotheses.

However, the LSQ program very often fails to converge at the desired level of accuracy (one percent level). On the other hand, the iterative Zellner's technique (a user written program in APL using double precision) does not fail to converge even with relatively stronger convergence criteria. Thus if a program fails with LSQ, it can often be estimated by IZE.[11]

Separability restrictions are derived in Chapter 2.C. It may be noted there that strong homotheticity (conditions 47) or strong homothetic separability (conditions 51) are linear restrictions, while weak homotheticity (conditions 43) or weak homothetic separability (conditions 48) are non-linear restrictions. In both cases, given the log of

the likelihood function for the constrained and unconstrained models, one can apply the LR test. For the linear restriction it is also possible to apply a standard F-test (see Theil 1970 p 314) which requires only the unrestricted estimates. However, the justification for this test is asymptotic since it relies on the feasible GLS estimates whose small sample distributions are, in general, unknown. Note that the F distribution tends to the χ^2 as the degrees of freedom of the denominator in F tends to infinity.

If the LSQ program does not converge at the desired level of accuracy an LR test cannot be used and one must use the F-test with the IZE estimates. However, for non-linear restrictions, if the LSQ program does not converge, it is not possible to apply an F-test using the unrestricted IZE estimates. In this situation one can apply a Wald test. This test is based on linearization of the non-linear restrictions by a Taylor series expansion of the functional restrictions (Buse, 1981).

The Wald statistic for testing non-linear restrictions using unconstrained estimates can be calculated as follows. Let $\hat{\beta}$ be an asymptotically normal and efficient unconstrained estimator of the K by 1 vector β so that

$$\sqrt{T}(\hat{\beta}-\beta) \sim N(0, C^{-1})$$

where C is the asymptotic information matrix defined by

$$C=\lim_{T\to\infty} 1/T \left[-E\,\frac{\delta^2 \log L}{\partial\beta\partial\beta'}\right]$$

Then if $r(\beta)=0$ is a g by 1 vector of functional restrictions which defines the null hypothesis, the Wald statistic (W) is given by

$$W=r(\beta)^1(RC^{-1}R^1)r(\beta)$$

where $R=\frac{\partial r(B)}{\partial B^1}\Big|\beta=\hat{\beta}$ is a g by k matrix of rank g.

W is asymptotically distributed as $\chi^2(g)$ under the null hypothesis. For the set of share equations the C matrix can be consistently estimated by

$$C=X^1(\hat{\Sigma}^{-1}\otimes I)^{-1}X$$

where C is an np by np matrix, and p is the number of equations.

The attractive feature of this test statistic is that one has only to determine the appropriate efficient unconstrained estimates.[12]

4.B.1 The Wald Test and Seemingly Unrelated Regressions

In order to apply the Wald test to the homotheticity and separability hypotheses the matrix R and the set of functional restrictions $r(\beta)$ must be specified.

4.B.1.1 Weak Homotheticity

The non-linear restrictions are

$$d_{iQ}=\alpha_i\rho_Q \qquad i=L,\ K,\ E,\ R \qquad (17)$$

Since the constant ρ_Q is unknown and is not a member of the unconstrained parameter vector β, it should be eliminated as follows:

equation (17) implies

$$d_{iQ}/\alpha_i = \rho_Q \qquad i=L,\ K,\ E,\ R \tag{18}$$

and (18) can be written as

$$d_{LQ}/\alpha_L = d_{iQ}/\alpha_i \qquad i=K,\ E,\ R \tag{19}$$

showing that there are three independent restrictions. Using (19), the functional restrictions $r(\beta)$ can be written as

$$r(\beta) = \begin{bmatrix} r_1(\beta) \\ r_2(\beta) \\ r_3(\beta) \end{bmatrix} = \begin{bmatrix} d_{LQ}\alpha_K - \alpha_L d_{KQ} \\ d_{LQ}\alpha_E - \alpha_L d_{EQ} \\ d_{LQ}\alpha_R - \alpha_L d_{RQ} \end{bmatrix} = 0 \tag{20}$$

The matrix R is obtained as

$$R = \frac{\partial r(B)}{\partial B}\bigg|_{\beta=\hat{\beta}}$$

In this case R is found to be

$$R = \begin{bmatrix} -d_{KQ} & d_{LQ} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \alpha_K & -\alpha_L & 0 & 0 \\ -d_{EQ} & 0 & d_{LQ} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \alpha_E & 0 & -\alpha_L & 0 \\ -d_{RQ} & 0 & 0 & d_{LQ} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \alpha_R & 0 & 0 & -\alpha_L \end{bmatrix} \tag{21}$$

4.B.1.2 Weak Homothetic Separability (WHS)

Consider the WHS conditions outlined in Chapter 2.C.

(1) $\beta_{ij} = \alpha_i \rho_j \qquad i=L,\ K,\ E$ and $j=R,\ NR$

(2) $d_{iQ} = \alpha_i \rho_Q \qquad i=L,\ K,\ E$ (22)

Eliminating the unknown ρ_j (j=R, NR), the independent restrictions (1) can be written as

(a) $\beta_{LR}\alpha_K - \beta_{KR}\alpha_L = 0$

(b) $\beta_{LR}\alpha_E - \beta_{ER}\alpha_L = 0$

(c) $\beta_{LNR}\alpha_K - \beta_{KNR}\alpha_L = 0$

(d) $\beta_{LNR}\alpha_K - \beta_{KNR}\alpha_L = 0$ (23)

There are four independent restrictions.

Eliminating the unknown ρ_Q, the independent restrictions (2) can be written as

(i) $d_{LQ}\alpha_K - \alpha_L d_{KQ} = 0$

(ii) $d_{LQ}\alpha_E - \alpha_L d_{EQ} = 0$ (24)

There are two independent restrictions.

Combining (23) and (24), the set of restriction functions $r(\beta)$ is given by

$$r(\beta) = \begin{bmatrix} r_1(\beta) \\ r_2(\beta) \\ r_3(\beta) \\ r_4(\beta) \\ r_5(\beta) \\ r_6(\beta) \end{bmatrix} = \begin{bmatrix} \beta_{LR}\alpha_L - \beta_{KR}\alpha_L \\ \beta_{LR}\alpha_E - \beta_{ER}\alpha_L \\ \beta_{LNR}\alpha_K - \beta_{KNR}\alpha_L \\ \beta_{LNR}\alpha_E - \beta_{ENR}\alpha_L \\ d_{LQ}\alpha_K - d_{KQ}\alpha_L \\ d_{LQ}\alpha_E - d_{EQ}\alpha_L \end{bmatrix} = 0 \qquad (25)$$

From (25), it follows that homothetic separability of labour, capital, and energy from renewable and non-renewable resources implies 6 independent restrictions.

The matrix $R=\frac{\partial r(B)}{\partial B}\Big|_{\beta=\hat{\beta}}$ can be derived in the same manner as described in the previous case.

4.C.1.3 Weak Separability of R and NR from E

Consider the conditions

$\beta_{ij}=\alpha_i \rho_j \qquad i=R,\ NR \quad \text{and } j=E$

(i) $\beta_{ER}=\alpha_R \rho_E$

(ii) $\beta_{ENR}=\alpha_{NR} \rho_E$ (26)

From (26), eliminating ρ_E, the functional restriction $r(\beta)$ can be written as

$r(\beta)=\beta_{ENR}\ \alpha_R-\beta_{ER}\ \alpha_{NR}=0$ (27)

This gives one restriction.

4.C F-statistic and the Seemingly Unrelated Regression

In order to test a set of linear restrictions $R\beta=r$, where the matrix R is as defined above, β is a vector of parameters and r is a g-vector of specified values, an F-test can be applied. Under the null hypothesis $R\beta-r=0$, we can use the conventional F-statistic for testing a set of linear restrictions. In Chapter 2 we show that restriction (34) is in the form $\beta_{ij}=0$ and the F test applies. In this case the F-statistic has g and $(Ln-\sum_j k_j)$ degrees of freedom (where L is the number of equations and $k=\sum k_j$ is equal to the number of distinct parameters estimated).

Strong homotheticity or strong homothetic separability implies linear restrictions and either the LR or an F-test can be applied. However, to apply the LR test we need both unconstrained and constrained values of the log of the likelihood function and it may be the case that one of these estimations may not converge.[13] To apply an F-test as above one has to form the R matrix, imposing linear restrictions such that $R\beta=r$ or $R\beta-r=0$. For example, testing strong homothetic separability, the R matrix for the restrictions in 47 (Chapter 2) $d_{iQ}=0$, i=L, K, E, R can be obtained as

$$R=(0:I_4) \qquad (28)$$

where 0 is a 4 by 14 matrix of zero elements and I_4 is a 4 by 4 identity matrix showing that there are 4 independent restrictions (g=4), and r=0.

Similarly, we can test the hypotheses that

(i) $\beta_{RNR}=0$,

(ii) $\beta_{ER}=\beta_{ENR}=0$

using the same framework.

Footnotes to Chapter 4

1. The disturbances (u_i's, i=c, l, k, e, r and nr) may be attributed to a variety of random forces, including empirical deviations from purely competitive markets, non-maximization of profits and also measurement errors.

2. See Maddala (1977), p. 192.

3. See Fuss (1977), p. 91.

4. See Kmenta (1971), p. 517.

5. See Johnston (1972), p. 238. It follows from (6) that in the first stage the OLS estimates of β_i's is obtained as $\hat{\beta}_i=(X_i'X_i)^{-1}X_i'Y_i$ i=L, K, E, R and hence the residuals $\hat{u}_i$'s are calculated as $\hat{u}_i=Y_i-X_i\hat{\beta}_i$ i=L, K, E, R.

Finally, Σ_c is estimated as

$$\hat{\Sigma}_c = \begin{bmatrix} \frac{\hat{u}_L'\hat{u}_L}{n} & --- & \frac{\hat{u}_L'u_R}{n} \\ \vdots & & \vdots \\ \frac{\hat{u}_R'\hat{u}_L}{n} & --- & \frac{\hat{u}_R'\hat{u}_R}{n} \end{bmatrix}$$

where $\hat{\sigma}_{ij}=\frac{\hat{u}_i'\hat{u}_j}{n}$. Note that we dividing the residual sum of squares by n without accounting for the loss of degrees of freedom. The problem of correcting for degrees of freedom is a difficult one. See Theil (1971), p. 301 and footnotes 13 on p. 322 and pp. 649-652.

6. See Humphrey and Moroney (1975), p. 65.

7. See "Time Series Processor (TSP), 1973, version.

8. For example, consider the system of equations in (3). The design matrix is of order 64 by 18, for n=16,

k=18, the number of unknown parameters.

9. Estimated values of α_0, α_Q, β_{QQ} cannot be obtained from the estimation of share equations.

10. See Theil (1971), p. 396.

11. Another problem with the version of TSP used here (version 2.4) is that the standard errors are slightly upward biased. Comparisions of estimates from this and a later version (3.5) indicate only slight differences.

12. For details see Buse (1981).

13. This in fact happened in a few cases. Those cases will be identified in the empirical results.

Chapter 5. Empirical Results

In this chapter we present the econometric results for the production-cost share model. Before doing so, however, we survey for background purposes the trends in prices and cost shares over the 1961-76 study period. Input prices have changed considerably during seventies, particularly since 1973. This is mainly because of the sharp increase in world energy prices in 1973 which had distinct and widespread repercussions. Cost shares have changed accordingly. Therefore, the analysis of input prices and cost shares may help the interpretation of the econometric results presented in the latter sections of the chapter.

Problems with the measurement of inputs and their prices were discussed in Chapter 3. A detailed description of the construction of variables and the sources of data are given in Appendix 1. The construction of aggregate price variables is accomplished by using a Divisia index aggregator.[1] Aggregate input prices and cost shares are shown in Table 1 and 2 respectively in Appendix 2.

The organization of this chapter is as follows: In section A we analyse the trend of price changes; in section B we discuss the nature of input shares and intensity of resource use by industry; in section C we present the results of tests of homotheticity and separability as outlined in Chapter 4. In section D we present the

empirical results with interpretations and some discussion of their implications. This later section consists of three sub-sections. In sub-section 1 we analyse the results of total manufacturing and compare them with previous studies of total manufacturing; in sub-section 2, as a representative sector of the two-digit industries, we analyse the results of the food industry and compare them with previous food manufacturing studies. The analysis of the rest of the two-digit industries is similar to that of the food industry. In sub-section 3, the general pattern of important results across industries are discussed and analysed.

5.A Price Trends

The price indexes of the industries are shown in Table 1 of Appendix 2.[2] To summarize the price trends we consider the graph of input prices for the total manufacturing sector shown in figure 5.1. Note there that the prices of labour exhibit a consistent increasing trend over the period 1961-76. We also note that the labour price has almost tripled during that period.

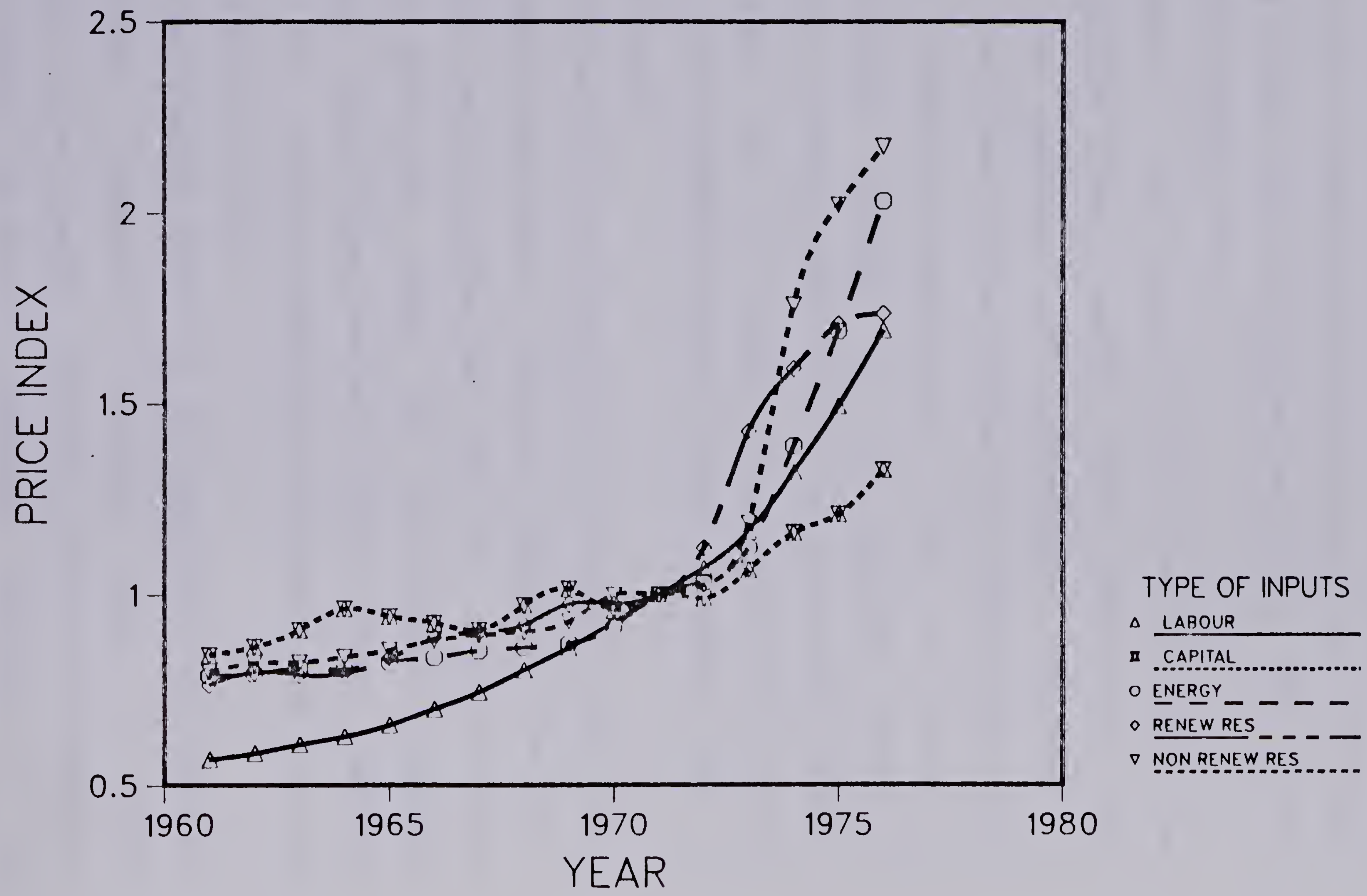
Unlike the price of labour, the price of capital does not show a regular upward trend. On the contrary, cyclical fluctuations can be observed with peaks in 1964 and 1969 but with continuous upward movement during the seventies. Reasons for these fluctuations may be changes in the effective tax rate, the real rate of return, and the investment tax credit since the rental price of capital is

dependent on these factors.[3]

It can be seen in the graph that until 1969 energy prices were fairly stable. After that it increased steadily until 1973. However, since 1973 energy price increases have been quite dramatic. The main reason for this substantial increase in the energy price is the 1973 world oil embargo by the OPEC countries.

Figure 5.1

PRICE TRENDS IN MANUFACTURING



It can be seen that the prices of renewable resources increased quite steadily and continuously (until 1971) and then with a higher rate of increase towards the end of the sample period (beyond 1971).

Movements in the price of non-renewable resources largely parallel those of energy. Since crude mineral oils is one of the components of non-renewable resources, a tremendous increase in the price of crude mineral oils (again due to OPEC's influence since 1973) contributed to the substantial increase in the aggregate price of non-renewable resources (PNR) of the manufacturing sector. It is evident from the above graph that after 1973 the increase in non-renewable resource prices exceeds that of all other inputs.

It is clear from the analysis of the price trends that in all cases prices rose at relatively moderate rates until 1971. Since then all prices have risen at a much faster rate, the prices of energy and non-renewable resources particularly. While these movements partly reflect general inflation the relative changes are important (see Angivine (1980) and Ellison (1979)).

Somewhat similar trends can be observed in the cases of the two-digit industries although there is often considerable interindustry variation (Table 1 of Appendix 1). For example, the price of renewable resources to the textile industry fluctuates considerably rather than increasing continuously over the whole period as for total

manufacturing. Similarly, the price of non-renewable resources to the chemicals industry has risen less rapidly than that for the petroleum and coal products industry and both diverge from the aggregate trend which, of course, obscures such interindustry variations.

5.B Cost Shares

The cost shares of the inputs are shown in Table 2 of Appendix 2. For summary purposes we again consider the shares of the total manufacturing sector. The average shares of total manufacturing inputs over the period 1961-76 are 39.43% for labour, 17.80% for capital, 3.65% for energy, 17.97% for renewable resources and 21.15% for non-renewable resources. Labour share is the highest and energy share is the lowest. It can be seen in figure 5.2 that cost shares exhibit some variation, particularly after 1970. Note, for example, that labour's share is initially constant, increases to a stable plateau, increases again in 1972, falls sharply until 1974 and then rises again. Being the smallest, the variations of the energy share cannot be recognized on the single scale plot although it is considerable. Therefore, a separate plot for the energy share is drawn in figure 5.3. It is evident in figure 5.3 that the energy share fell gradually from 4.0 to 3.4 percent and then rose back sharply to the 4 percent level by 1976.

Figure 5.2

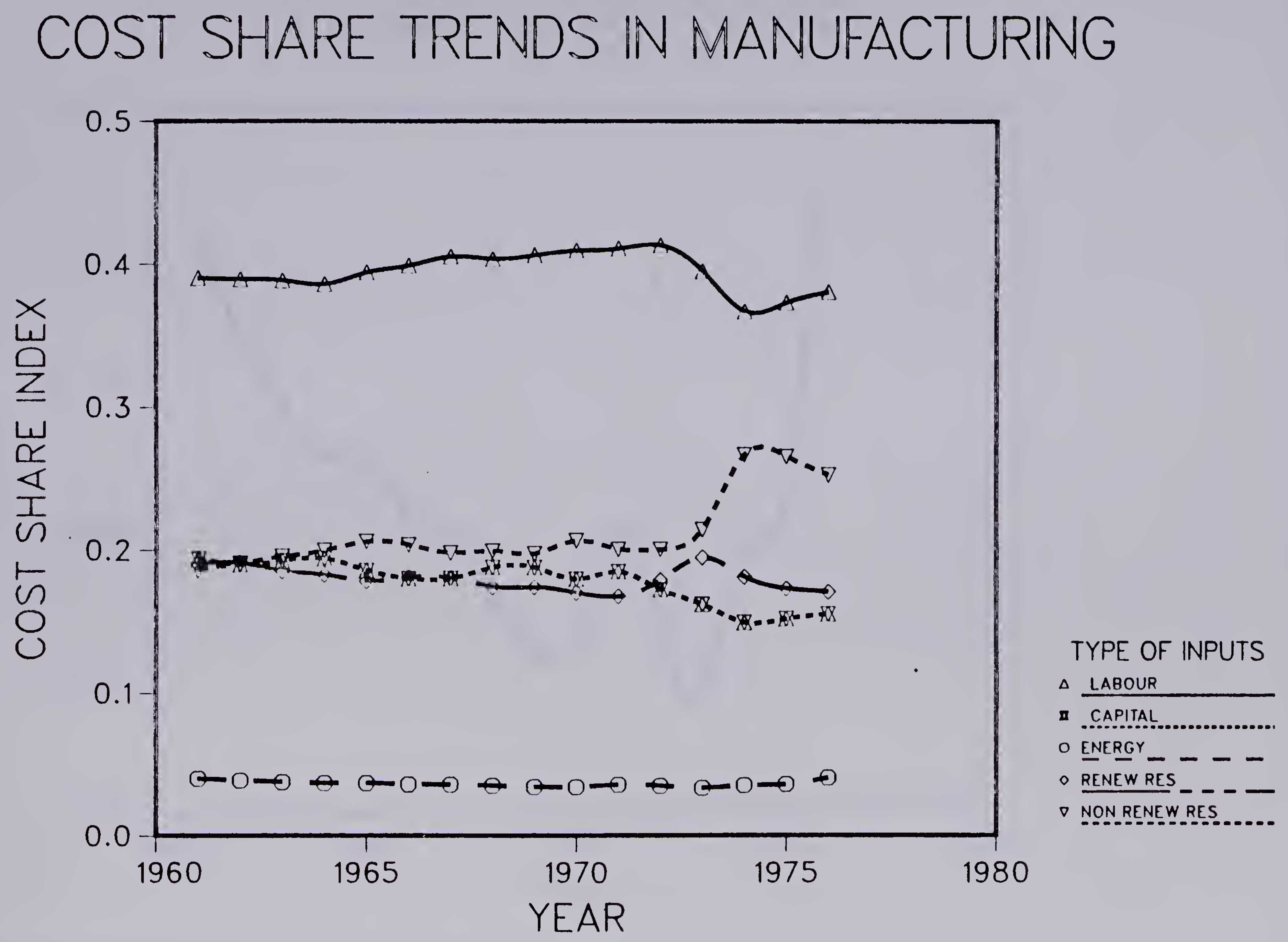
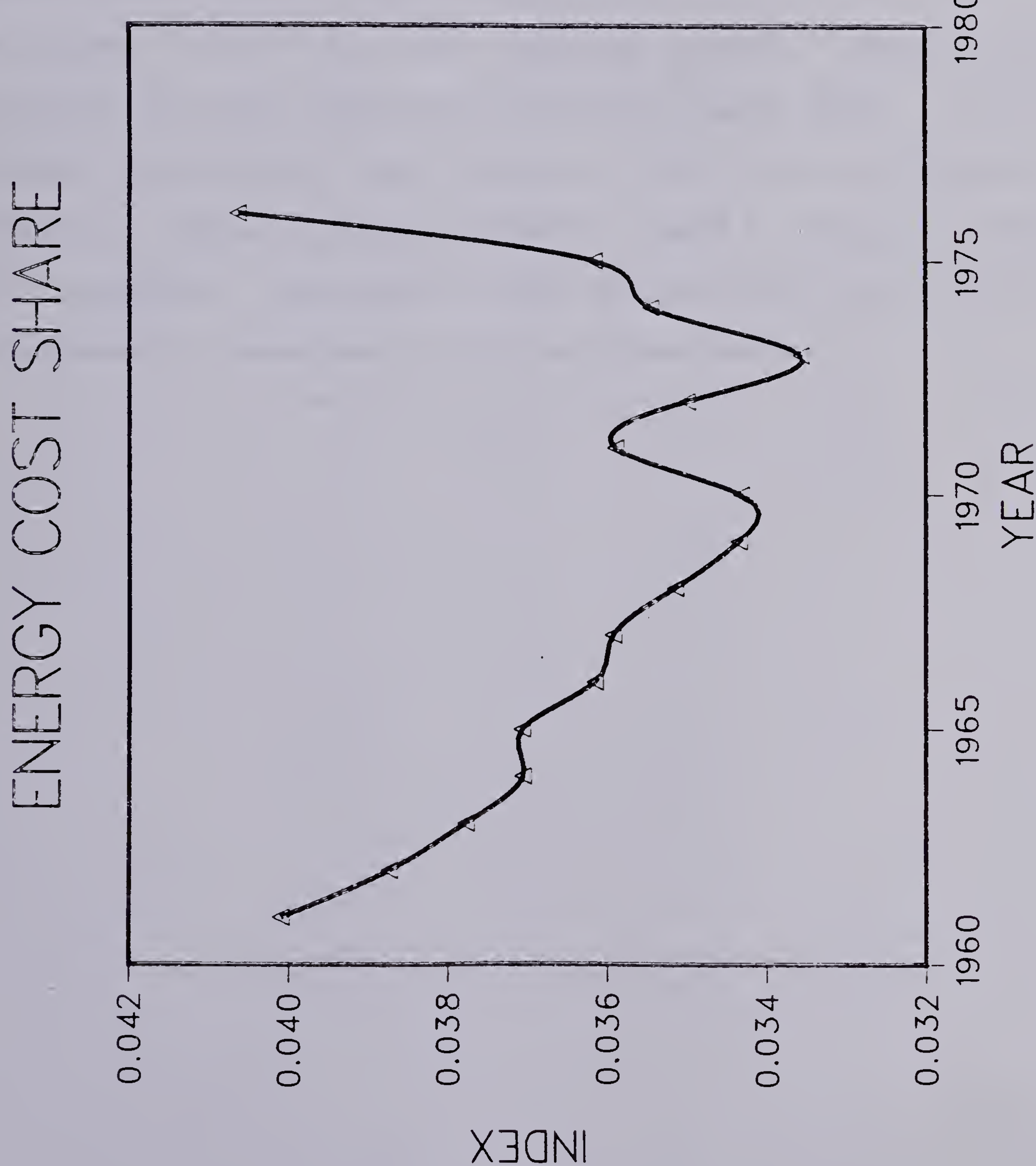

COST SHARE TRENDS IN MANUFACTURING
COST SHARE INDEX
0.5
0.4
0.3
0.2
0.1
0.0
1960
1965
1970
1975
1980
YEAR
TYPE OF INPUTS
LABOUR
CAPITAL
ENERGY
RENEW RES
NON RENEW RES

Figure 5.3


ENERGY COST SHARE
INDEX
0.042
0.040
0.038
0.036
0.034
0.032
1960
1965
1970
1975
1980
YEAR

5.B.1 Nature of Cost Shares Across Industries

Input cost shares vary substantially across industries (Table 5.1). In most cases the average labour share is the highest although there are many exceptions (e.g. food, tobacco, wood, primary and petoleum and coal products industries). Labour shares range from a low of .11 in petroleum to .88 in the clothing sector. Energy and resource (R or NR) shares are typically quite small. At its largest, the energy share is about 0.09 in the non-metallic industry. Resource shares, however, reach a high of 0.56 for renewable resources in food manufacturing and 0.74 for non-renewable resources in the petroleum sector.

TABLE 5.1

Average Cost Shares of Inputs
(1961 - 1976)

	SL	SK	SE	SR	SNR
1. Food	0.27689	0.12534	0.01844	0.56488	0.01445
2. Tobacco	0.34243	0.13107	0.00805	0.51845	0
3. Rubber	0.71734	0.2312	0.0326	0	0.01887
4. Leather	0.77302	0.09207	0.01529	0.11961	0
5. Textiles	0.66136	0.27726	0.03747	0.01945	0.00438
6. Knitting	0.80542	0.17282	0.02167	0	0
7. Clothing	0.88521	0.05046	0.00843	0.0559	0
8. Wood	0.39086	0.11463	0.02348	0.46213	0.00891
9. Furniture	0.71772	0.07862	0.01693	0.11559	0.07114
10. Paper	0.39581	0.27294	0.08704	0.22527	0.01894
11. Printing	0.78659	0.19628	0.01128	0	0.00585
12. Primary	0.26518	0.15614	0.05691	0	0.52177
13. Metal Fab.	0.50717	0.11521	0.01609	0	0.36152
14. Machinery	0.64461	0.14893	0.01314	0	0.19331
15. Transport	0.58636	0.19671	0.01678	0.00766	0.19249
16. Elec.	0.63937	0.11535	0.01356	0	0.23172
17. Non-met.	0.48149	0.26551	0.08946	0	0.16354
18. Petroleum	0.11079	0.13543	0.01054	0	0.74324
19. Chemicals	0.48168	0.36323	0.07179	0.01481	0.064
20. Misc.	0.70992	0.05848	0.01554	0.02085	0.16821
21. Total	0.39443	0.17797	0.03645	0.17972	0.21153

The trend in labour's share of expenditures varies substantially among manufacturing industries (Appendix 2, Table 2). For several cases, the labour share has been rising; for example, paper, rubber, leather, textiles, printing, primary and a few others. Many, however, show a slight increase in labour's share followed by a slight decline, more like that for total manufacturing. One of the exceptional cases is the petroleum and coal products industry whose labour share initially fluctuates and then declines (due to the large increase in the price of non-renewable resource inputs).

As for the other inputs, capital shares generally exhibit a variable declining trend. Energy shares for the most part are fairly uniform across industries. Generally, there is a slight declining trend followed by an increase towards earlier levels after 1973. Renewable resource shares do not exhibit any definite trend in these industries. Non-renewable resource shares, however, generally show a marked increase in the latter years but the pattern is not uniform among the industries using that type of resource. While petroleum shows a sharp increase, the non-renewable resource cost shares declines for paper.

5.B.2 Nature of Share Intensity Across Industries

Industries can be classified on the basis of their factor intensity as reflected in the average cost shares shown in Table 5.1. The criterion of classification is

taken to be those industries whose average share falls above the average share across industries. Those industries falling in this category are considered as input intense. The classification of industries according to the above criterion as input intensive industries are shown in Table 5.2. It can be seen that there are four renewable and four non-renewable resource intensive industries. The behaviour of these industries will be highlighted in the econometric analysis.

Table 5.3 shows the intensity of input use as reflected by relative input cost shares. It is evident that in most cases (16 out of 21) the labour share is the highest (i.e. largest cost share, H) within the industry and in most cases energy share is the lowest (i.e. smallest, L). The capital share is in between. Where used, renewable and non-renewable resource shares are in a few cases either the highest or the lowest.

TABLE 5.2

Input Intense Industries

	LABOUR INTENSE*	CAPITAL INTENSE	ENERGY USE USE	RENEWABLE RESOURCE USE	NON-RENEWABLE RESOURCE
1.				Food	
2.				Tobacco	
3.	Rubber	Rubber			
4.	Leather				
5.	Textiles	Textiles	Textiles		
6.	Knitting				
7.	Clothing				
8.	Wood			Wood	
9.	Furniture				
10.	Paper	Paper	Paper	Paper	
11.	Printing	Printing			
12.			Primary		Primary
13.	Metal Fab.				Metal Fab.
14.	Machinery				
15.	Transport	Transport			
16.	Electrical Products				Electrical Products
17.	Non-metallic	Non-metal	Non-metallic		
18.					Petroleum
19.	Chemicals	Chemicals	Chemicals		
20.	Miscellaneous				

* Industries whose average share falls above the average share (that is, of total manufacturing).

TABLE 5.3

Relative Input Shares by Industry

Industry	Labour	Capital	Energy	Renewable* Resources	Non-renewable* Resources
1. Food			L	H	
2. Tobacco			L	H	
3. Rubber	H				L
4. Leather	H		L		
5. Textiles	H				L
6. Knitting	H		L		
7. Clothing	H			L	
8. Wood				H	L
9. Furniture	H		L		
10. Paper	H				L
11. Printing	H				L
12. Primary			L		H
13. Metal Fab.	H		L		
14. Machinery	H		L		
15. Transport	H			L	
16. Electrical Products	H		L		
17. Non-metal.	H		L		
18. Petroleum			L		H
19. Chemicals	H			L	
20. Misc.	H		L		
21. Total	H		L		

* for industries using those resources

H: highest in industry

L: lowest in industry

5.C Homotheticity and Separability

5.C.1 Tests of Hypotheses Concerning Alternative Production Structures

In this study the maintained hypothesis is the non-homothetic translog cost function. Against this, alternative forms of the cost function are tested, such as the hypotheses of strong and weak homotheticity, homothetic separability and other separability hypotheses.

The translog function may act either as an approximation or as the exact representation of the production function. The approximate translog form implies a flexible second order approximation of the true function achieved by a Taylor series expansion. Separability restrictions determine which form the translog function represents (Denny and Fuss, 1977). An exact form requires an additional constraint.[4] In this study the translog function is treated as an approximate form as implied by our separability conditions.[5]

5.C.2 Strong and Weak Homotheticity

The results of the strong homotheticity and weak homotheticity tests are shown in Table 5.4. In cases where the likelihood ratio test could not be performed due to the nonconvergence of the non-linear least squares program, either an F-test or a Wald test was applied based on the results using Zellner's iterative method.[6] In those cases test results are shown in Table 5.5 and Table 5.6. Results in Table 5.5 show the F-values in testing strong

homotheticity and those in Table 5.6, the Wald test values for testing weak homotheticity.

TABLE 5.4

Strong and Weak Homotheticity

INDUSTRY	L.F. Maintained Hypothesis	L.F.[1] Strong Homotheticity	d.f.	$\chi^2(H)$[2]	Decision[3] (H.M.)	L.F. Weak Homothe-ticity	d.f.	$\chi^2(W.H)$	Decision[3]
1. Food	a	263.513	4	a	a	-58.812	3	a	a
2. Tobacco	157.647	133.743	3	47.808	Rejected	136.496	2	42.302	Rejected
3. Rubber	157.397	153.453	3	7.888	Rejected	156.384	2	2.026	Accepted
4. Leather	126.865	125.581	3	2.568	Accepted	96.071	2	61.588	Rejected
5. Textiles	a	234.178	4	a	a	234.765	3	a	a
6. Knitting	105.147	93.928	2	22.438	Rejected	101.287	1	7.72	Rejected
7. Clothing	178.465	164.745	3	27.440	Rejected	168.821	2	19.288	Rejected
8. Wood	a	190.725	4	a	a	58.812	3	a	a
9. Furniture	212.652	208.337	4	8.63	Accepted	208.480	3	8.344	Rejected
10. Paper	a	211.043	4	a	a	211.684	3	a	a
11. Printing	202.322	181.741	3	41.162	Rejected	181.737	2	41.170	Rejected
12. Primary	128.207	113.988	3	28.438	Rejected	-41.352	2	--	Rejected
13. Metal fab.	150.578	135.655	3	29.826	Rejected	145.080	2	10.996	Rejected
14. Machinery	142.600	124.392	3	36.416	Rejected	134.725	2	15.750	Rejected
15. Transport	224.834	214.634	3	22.400	Rejected	215.683	3	18.302	Rejected
16. Electrical Products	185.783	153.172	3	65.222	Rejected	174.953	2	21.660	Rejected
17. Non-metal.	140.783	122.531	3	36.522	Rejected	130.038	2	21.508	Rejected
18. Petroleum	158.040	118.875	3	78.330	Rejected	142.450	2	31.180	Rejected
19. Chemicals	203.304	199.119	4	8.37	Accepted	204.090	3	a	a
20. Misc.	209.302	194.221	4	30.162	Rejected	201.252	3	16.100	Rejected
21. Total	231.740	202.445	4	58.590	Rejected	228.202	3	7.440	Accepted

"a" indicates the cases in which LSQ program did not converge. In these cases strong homotheticity and weak homotheticity results are shown in tables 5.9, 5.10 respectively based an alternative program (iterative Zellner, IZE).

1: Log of likelihood function.

2: Calculated value of Chi-square for testing homotheticity

3: In all cases hypothesis are rejected at the 5% level of significance (χ^2 4df = 9.49, χ^2 3df = 7.81, χ^2 2df = 5.99, χ^2 1df = 3.84)
(5% level) (5% level)

H.M: Strong homotheticity of model

W.H: Weak homotheticity of model

The values of the log of the likelihood function of the unconstrained model (maintained hypothesis) and those for the constrained model when the strong homotheticity and weak homotheticity constraints are imposed are shown in columns 2, 3 and 7 respectively of Table 5.4. It can be seen in column 6 of Table 5.4 that at the 5% level of significance, the hypothesis of strong homotheticity is rejected in most cases (exceptions are leather, furniture and chemicals), the rate of rejection is more than 82 percent. Similarly, it can be noted in column 10 of Table 5.4 that at the 5% level of significance, the hypothesis of weak homotheticity is rejected in the majority of cases (except rubber, and total manufacturing), the rate of rejection is more than 87 percent. It should also be noted that in the case of the rubber industry that strong homotheticity is only marginally rejected; also in the case of total manufacturing the hypothesis of weak homotheticity is only marginally accepted.[7]

Results in Table 5.5 and Table 5.6 show that both strong and weak homotheticity hypotheses are rejected in the remaining cases. Therefore, on the basis of the above test results it can be concluded that the maintained hypothesis is the appropriate structure for the translog cost function in this study. This implies that the constant returns to scale specification is not appropriate.[8]

TABEL 5.5

Strong Homotheticiy

INDUSTRY	D.F.	F-VALUE	5% F-VALUE	Decision
Food and Beverages	4,46	4.233	2.57	Rejected
Textiles	4,46	3.044	2.57	Rejected
Wood	4,46	19.157	2.57	Rejected
Paper	4,46	15.240	2.57	Rejected
Chemicals	4,46	8.677	2.57	Rejected

D.F. = Degrees of freedom

TABLE 5.6

Weak Homotheticity*

INDUSTRY DECISION	D.F.	χ^2-VALUE	5% χ^2VALUE	
Food and Beverages	3	23.291	7.815	Rejected
Textiles	3	12.598	7.815	Rejected
Wood	3	83.974	7.815	Rejected
Paper	3	73.665	7.815	Rejected
Chemicals	3	37.769	7.815	Rejected

* This is based on the Wald Test

5.C.3.1 Homothetic Separability of the Resource sector

The homothetic separability test is performed in the case of testing separability of the resource sector, that is, the weak separability of L, K, E from R and NR. These results are shown in Tables 5.7 and 5.8. Tables 5.7 and 5.8 show that, with the exception of leather and clothing, the hypothesis that labour, capital and energy are separable from resources is rejected. This result has a very important implication in terms of firms' decision in input use. It means that changes in the prices of R and NR will affect firms' decisions in the use of other factors as well, namely L, K and E. The above results also indicate that the specification of the cost function excluding resources as inputs will lead to serious bias in the estimated parameters.[5]

If resources (R and NR) are not separable from capital, labour and energy, are renewable and non-renewable resources individually separable? To investigate this question the separability test is performed between R and NR for nine industries including total manufacturing. The reason for testing only nine cases is that according to our definition of renewable and non-renewable resources only eight out of the twenty two-digit industries as well as total manufacturing use both resources.

TABLE 5.7

Homothetic Separability of the Resource Sector

	Industry	L. F.[1] Maintained	L.F.[1] W.H.S.[2] of R. Sector	D.F	χ^2 (W.H.S.)[2]	Decision
1.	Food	a	a	7	a	a
2.	Tobacco	157.647	-46.293	4	a	a
3.	Rubber	157.397	147.807	4	19.180	Rejected
4.	Leather	126.865	124.948	4	3.834	Accepted
5.	Textiles	a	a	7	a	a
6.	Knitting	105.147				
7.	Clothing	178.465	173.916	4	0.098	Accepted
8.	Wood	a	a	7	a	a
9.	Furniture	212.652	203.815	7	17.674	Rejected
10.	Paper	a	a	7	a	a
11.	Printing	202.322	190.309	4	24.026	Rejected
12.	Primary	128.207	44.867	4	a	a
13.	Metal Fab.	150.578	138.194	4	24.768	Rejected
14.	Machinery	142.600	133.411	4	18.378	Rejected
15.	Transport	224.834	199.557	7	50.554	Rejected
16.	Electrical Products	185.783	179.166	4	13.234	Rejected
17.	Non-Metallic	140.792	131.904	4	17.776	Rejected
18.	Petroleum	158.040	142.995	4	30.09	Rejected
19.	Chemicals	a	a	7	a	a
20.	Miscellaneous	209.302	192.393	7	33.818	Rejected
21.	Total	231.740	223.721	7	16.038	Rejected

a. See footnote in Table 5.4.

1. See footnote 1 in Table 5.4.

2. W.H.S.: Weak Homothetic Separability.

TABLE 5.8

Homothetic Separability of the Resource Sector

Industry	D.F.	χ^2 Value*	5% χ^2 Value	Decision
Food and Beverages	7	45.045	14.067	Rejected
Textiles	7	88.319	14.067	Rejected
Wood	7	129.894	14.067	Rejected
Paper	7	123.044	14.067	Rejected
Chemicals	7	85.130	14.067	Rejected
Tobacco	4	--	--	--
Primary	4	--	--	--

* This is based on the Wald Test

The results are reported in Table 5.9. The important features of the results in Table 5.9 are that in the cases of renewable resource intense industries, namely the food, paper and total manufacturing (exception, the wood industry)[10], the hypothesis that R and NR are separable is rejected. In the other cases it is accepted.[11]

5.C.4.2 Separability of Resources (R and NR) from Energy

In this case both weak and strong separability tests are performed. The results of strong separability are shown in Table 5.9 and those of weak separability are shown in Table 5.10.

The results based on strong separability (in Table 5.9) show that the hypothesis that R and NR are separable from energy (E) is rejected in most cases (with the exception of textiles, furniture and total manufacturing). Since the hypothesis is rejected in most cases, this implies the necessity of including resources as inputs in models of this kind.

TABLE 5.9

Separability Within Resources (Between R, NR) and Between either Energy and R or between Energy and NR

INDUSTRY	L.F. Maintained Hypothesis	HO BRNR[1] = 0	$\chi^2(1)$ (Decision)	HO BER[2] = 0 BENR[2] = 0	$\chi^2(2)$ (Decision)
Food and Beverages	--	F*-value 23.745	Rejected	F*-value 41.966	Rejected
Textiles	--	F*-value 2.623	Accepted	F*-value 1.659	Accepted
Wood	--	F*-value 1.018	Accepted	F*-value 9.084	Rejected
Furniture	212.652	L.F. 211.191	.922 Accepted	L.F. 210.570	4.164 Accepted
Paper	--	F*-value 7.608	Rejected	F*-value 11.171	Rejected
Transport	224.834	L.F 224.449	.770 Accepted	L.F. 221.013	7.642 Rejected
Chemicals	--	F*-value 2.324	Accepted	F*-value 24.5066	Rejected
Misc.	209.302	L.F. 208.647	1.310 Accepted	L.F. 204.369	9.866 Rejected
Total	231.740	225.252	12.976 Rejected	L.F. 229.972	3.640 Accepted

* F-test, in cases where log of likelihood function (L.F.) could not be obtained (due to non-convergence of NLSQ program), an F-test is based on iterative Zellner's estimates.

1) BRNR = 0 is the condition for R and NR being additive or independent in the given translog specification.

2) BER, BENR, as in (1) imply independence of E and R and E and NR respectively.

TABLE 5.10

Weak Separability Between Energy and Renewable or Non-renewable Resources

INDUSTRY	L.F. Maintained Hypothesis	L.F. H: $BER=\rho E*AR$ $BENR=\rho E*ANR$	$\chi^2(2)$ (L.R.)	Minimum* χ^2	Decision
Food and Beverages	--	--	--	.585	Accepted
Textiles	--	--	--	.002	Accepted
Wood	--	--	--	1.387	Accepted
Furniture	212.652	202.002	21.3	--	Rejected
Paper	--	--	--	.683	Accepted
Transport	224.834	190.932	7.642	--	Rejected
Chemicals	--	--	--	13.287	Rejected
Miscell-aneous	209.302	209.301	9.866	--	Rejected
Total	231.740	225.977	13.326	--	Rejected

L.F. = log of likelihood function
L.R. = likelihood ratio

$\chi^2(1)$ .05 = 3.841
$\chi^2(2)$ .05 = 5.991

* See footnote in Table 5.4

TABLE 5.11

Separability of Energy and Renewable or Non-renewable Resources

INDUSTRY	L.F.[1] Maintained Hypothesis	L.F. BER = 0	$\chi^2(1)$	Decision
Tobacco	157.647	153.770	7.754	Rejected
Rubber	157.397	155.462	3.870	Rejected
Leather	126.865	126.212	1.306	Accepted
Clothing	178.465	177.655	1.620	Accepted
Printing	202.322	202.045	.544	Accepted
Primary	128.207	128.204	.006	Accepted
Metal fab.	150.578	150.247	.662	Accepted
Machinery	142.600	142.505	.190	Accepted
Electrical Products	185.783	180.740	10.086	Rejected
Non-metallic	140.792	140.761	.062	Accepted
Petroleum	158.040	151.698	12.684	Rejected

χ^2 (.05), (1) = 3.841

1: See footnote 1 of Table 5.4

Weak separability of R and NR from E give somewhat different results (Table 5.10) from those of the strong separability case. For example, in the cases of food, wood and paper, the hypothesis is accepted, while it is rejected in the case of the strong separability hypothesis, but rejected for furniture when accepted earlier. In the case of the total manufacturing sector, strong separability is accepted, while weak separability is rejected. Therefore, in general terms (either strongly or weakly) the the separability hypothesis is rejected. This certainly indicates that it is desirable to distinguish among E, R and NR.

Finally, the cases in which the industries (other than those in Table 5.10) use only either R or NR, the results of testing the hypothesis of the separability of R (or NR) from energy are shown in Table 5.11. The decision column of Table 5.11 shows that the hypothesis is rejected only in four cases (tobacco, rubber, electrical products and petroleum) and in other cases the hypothesis is accepted. However, rejecting the hypothesis in a few cases, at least implies that the separability of R or NR from E is not generally true.

Discussion of the relevant test statistics has been given in Chapter 4.

5.D Empirical Results of Estimated Elasticities

Estimates of own elasticities of demand (η_{ii}), cross elasticities of demand (η_{ij} and η_{ji}) and cross elasticities

of substitution σ_{ij} of the translog cost function for Canadian manufacturing, 1961-76 are presented in Tables 5.12, 5.13, 5.14 and 5.15 respectively. These values are calculated at the mean. The last column in each table indicates that the parameters reported are based on either a homothetic or a nonhomothetic translog cost function.[12]

Ideally one would like to know the standard error of the estimates of these parameters. Assuming that shares (S_i, S_j) are non-stochastic (constant) the asymptotic variances of σij and σii can be obtained as follows:[13]

a(i) $Var(\sigma ij)=Var(\beta ij)/S_i^2 S_j^2$

a(ii) $Var(\sigma ii)=Var(\beta ii)/S_i^4$

Again assuming that input shares are non-stochastic, the asymptotic variance of ij and ii can be obtained as

b(i) $Var(\eta ij)=Var(\beta ij)/S_i^2$

b(ii) $Var(\eta ii)=Var(\beta ii)/S_i^2$.

These standard errors were calculated, however, are not reported since firstly, these are not usually reported and secondly, it would be more appropriate to treat the shares as stochastic.[14]

It has been verified that the estimated parameters satisfy the concavity condition of the cost function for almost every observation in the sample period. Positivity of the cost shares is also satisfied. Therefore, it appears that for most of the industries the translog cost function is well behaved for the given sample period.[15]

TABLE 5.12

OWN PRICE ELASTICITIES OF FACTOR DEMAND

INDUSTRY		LABOUR	CAPITAL	ENERGY	RENEWABLE RESOURCES	NON-RENEWABLE RESOURCES	
1.	Food	-.28358	-.27607	-.12984	-.02639	-.51406	NH
2.	Tobacco	-.15490	0.09251	-.33640	-.02318	*	NH
3.	Rubber	-.13054	-.30134	-.01573	*	0.00000	NH
4.	Leather	-.08712	-.33994	-.69545	-.35523	*	NH
5.	Textiles	-.15652	-.39957	-.39335	-.45624	1.62648	HM
6.	Knitting	-.05024	-.07880	-.97783	*	*	NH
7.	Clothing	-.03293	-.11985	-.75503	-.30078	*	HM
8.	Wood	-.38462	-.29497	-.64069	-.27585	-3.86650	NH
9.	Furn.	-.21923	-.81634	-.11705	-.13409	-1.30728	HM
10.	Paper	-.18878	-.47193	.25141	-.09555	0.0000	NH
11.	Printing	-.00405	-.03552	-.63126	*	-.32226	HM
12.	Primary	-.06820	-.46740	-.53310	*	-.13900	NH
13.	Met Fab.	-.23576	-.53838	-.20001	*	-.04561	HM
14.	Mach.	-.28738	-.24756	-.35338	*	-.39618	HM
15.	Trans.	-.45967	-.27359	-.24882	-.50841	-.93024	HM
16.	Elec.	-.39378	-.49263	-.15750	*	0.74457	HM
17.	Non-met.	-.30856	-.56028	-.06658	*	-.74286	HM
18.	Petro. & Coal Prod.	-.30838	-.00328	-.04956	*	-.11616	NH
19.	Chem.	-.39151	-.35103	-.66550	-.02255	-.04749	HM
20.	Misc.	-.25981	-.83909	-1.54002	-1.2249	-10460	HM
21.	TOTAL	-.32148	-.52935	-40791	-.07768	-.04255	NH

NH: Non-homothetic model, HM: Homothetic model
Elasticities are calculated at mean values.

TABLE 5.13: CROSS ELASTICITIES (ηij) OF FACTOR DEMAND

Industry	LK	LE	LR	LNR	KE	KR	KNR	ER	ENR	RNR	MODEL
1. Food	.14143	.01287	.08023	.04906	.01978	-.08220	.02606	.23764	-.43541	-.00246	NH
2. Tobacco	.07469	.00966	.07054	*	-.00731	-.09533	*	.04447	*	*	NH
3. Rubber	.09587	.03496	*	-.00029	-.04172	*	.04559	*	-.45782	*	NH
4. Leather	.03052	.01256	.04404	*	.00100	.08273	*	.05437	*	*	NH
5. Textiles	.14975	.03285	-.02339	-.00269	-.04920	.08501	.00656	.19517	-.01755	-.33255	HM
6. Knitting	.02051	.03001	*	*	-.01677	*	*	*	*	*	NH
7. Clothing	.00752	.00726	.01823	*	-.01336	.00132	*	.07264	*	*	HM
8. Wood	.03006	.01818	.26316	.07321	.01332	.12825	.05090	.34802	-.07510	.00379	NH
9. Furniture	.11264	.00937	.02315	.07406	-.07471	-.24358	.10632	.13626	.93050	.13604	HM
10. Paper	.08564	.04765	.02232	.033179	.03338	.29516	.01921	-.55406	-.01867	-.08722	NH
11. Printing	.00211	.00392	*	-.00198	.01496	*	.01210	*	.09768	*	HM
12. Primary	.05938	.05295	*	-.04413	-.03468	*	.40123	*	.38152	*	NH
13. Metal Fab	.16570	.00471	*	.06535	-.01966	*	-.17140	*	.19242	*	HM
14. Machinery	.10929	.01153	*	.16656	-.01875	*	-.20670	*	.00027	*	HM
15. Transport	.11569	.00905	.02132	.31362	-.01615	-.06579	.01067	.16468	-.04256	-.81186	HM
16. Electrical	.11071	.00054	*	.28254	-.01757	*	-.10344	*	.28136	*	HM
17. Non-metallic	.19921	.01452	*	.09482	-.04525	*	.24427	*	.12272	*	HM
18. Petroleum & Coal Products	-.24065	.02765	*	.52137	-.01478	*	.21494	*	-.05126	*	NH
19. Chemicals	.29074	.03011	-.01377	.08443	.01105	.01800	-.06975	.29552	.10253	-1.34914	HM
20. Miscellaneous	.13192	.01041	.02715	.09033	.14326	.10139	-.50107	.17912	.09682	-.24957	HM
21. TOTAL	.25712	.02224	.06810	-.02598	-.00676	-.09577	.06218	.04489	.15545	.01398	NH

TABLE 5.14: CROSS ELASTICITIES (η_{ji}) OF FACTOR DEMAND

Industry	KL	EL	RL	NRL	EK	RK	NRK	RE	NRE	NRR	MODEL
1. Food	.31242	.19315	.03933	.93975	.13445	-.01823	.22601	.00776	-.55560	-.09610	NH
2. Tobacco	.19515	.41099	.04659	*	-.11905	-.02410	*	.00064	*	*	NH
3. Rubber	.29746	.76944	*	-.01107	-.29589	*	.55866	*	-.79088	*	NH
4. Leather	.25622	.63506	.28459	*	.00603	.06368	*	.00695	*	*	NH
5. Textiles	.35721	.57985	-.79169	-.40628	-.36412	1.20627	.41559	.37421	-.15027	-1.48544	HM
6. Knitting	.09558	1.11103	*	*	.13324	*	*	*	*	*	NH
7. Clothing	.13189	.76238	.28864	*	-.08000	.00119	*	.01095	*	*	HM
8. Wood	.10250	.30273	.22258	3.21296	.06504	.03181	.65504	.01768	-.19795	.19649	NH
9. Furniture	1.02831	.39722	.14376	.74725	-.34694	-.16568	.11751	.01996	.22147	.22106	HM
10. Paper	.12418	.21667	.03922	.69332	.10466	.35763	.27684	-.21408	-.08582	-1.03725	NH
11. Printing	.00846	.27327	*	-.26556	.26031	*	.40561	*	.18821	*	HM
12. Primary	.10084	.24672	*	-.02243	-.09514	*	.12007	*	.04161	*	NH
13. Metal Fab	.72944	.14838	*	.09167	-.14079	*	-.05462	*	.00856	*	HM
14. Machinery	.47300	.56558	*	.55540	-.21248	*	-.15925	*	.00002	*	HM
15. Transport	.34486	.31600	1.63256	.95533	-.18929	-1.69009	.01091	.36098	-.00371	-.03230	HM
16. Electrical	.61364	.02552	*	.77959	-.14939	*	-.05149	*	.01647	*	HM
17. Non-met.	.36126	.07815	*	.27917	-.13430	*	-.39656	*	.06713	*	HM
18. Pet. & Coal Prod.	-.19637	.29070	*	.07772	-.18992	*	.03916	*	-.00073	*	NH
19. Chemicals	.39155	.21017	-.45022	.64544	.05727	.43709	-.39490	1.38481	.11231	-.31538	HM
20. Misc.	1.09551	.47584	.92466	.38123	.78823	.41578	-.25485	.13351	.00894	-.03093	HM
21. TOTAL	.56970	.24058	.14943	-.04844	-.03301	-.09484	.05232	.00911	.02679	.01188	NH

TABLE 5.15

CROSS ELASTICITIES OF SUBSTITUTION

INDUSTRY	σLK	σLE	σLR	σLNR	σKE	σKR	σKNR	σER	σENR	σRNR	
1. Food	1.12835	.69758	.14204	3.39400	1.07270	-.14552	1.80319	.42070	-30.12390	-.170132	NH
2. Tobacco	.5699	1.2002	.1361	*	-.9083	-.1839	*	.0858	*	*	NH
3. Rubber	.4147	1.0726	*	-.0154	-1.2798	*	2.4164	*	-24.2640	*	NH
4. Leather	.3314	.8215	.3682	*	.0655	.6916	*	.4545	*	*	NH
5. Textiles	.5401	.8768	-1.1971	-.6143	-1.3133	4.3506	1.4989	9.9880	-4.0109	-76.0183	HM
6. Knitting	.1187	1.3794	*	*	-.7710	*	*	*	*	*	NH
7. Clothing	.1490	.8612	.3261	*	-1.5851	.0236	*	1.2994	*	*	HM
8. Wood	.2623	.7745	.5695	8.2203	.5674	.2775	5.7145	.7531	-8.4324	.4252	NH
9. Furn.	1.4327	.5535	.2003	1.0411	-4.4128	-2.1073	1.4947	1.1789	13.0807	1.9125	HM
10. Paper	.31375	.54740	.09908	1.75167	.38345	1.31028	1.01428	-2.45958	-.98596	-4.60456	NH
11. Printing	.0108	.3474	*	-.3376	1.3262	*	2.0665	*	16.6885	*	HM
12. Primary	.3803	.9304	*	-.0846	-.6093	*	.7690	*	7312	*	NH
13. Met. Fab.	1.4382	.2926	*	.1807	-1.2220	*	-.4741	*	.5322	*	HM
14. Mach.	.7338	.8774	*	.8616	-1.4266	*	-1.0692	*	.0014	*	HM
15. Trans.	.5881	.5389	2.7842	1.6293	-.9623	-8.5918	.0554	21.5066	-.2211	-4.2177	HM
16. Elec.	.9598	.0399	*	1.2193	-1.2952	*	-.4464	*	1.2142	*	HM
17. Non-met.	.7503	.1623	*	.5798	-.5058	*	1.4936	*	.7504	*	HM
18. Petro.	-1.7770	2.6283	*	.7015	-1.4023	*	.2892	*	-.0690	*	NH
19. Chem.	.8016	.4303	-.9217	1.3212	.1579	1.2051	-1.0888	19.7870	1.6047	-21.1148	HM
20. Misc.	1.5431	.6703	1.3025	.5370	9.2206	4.8638	-2.9789	8.5927	.5756	1.4837	HM
21. TOTAL	1.4447	.6101	.3789	-.1228	-.1855	-.5329	.2940	.2498	.7349	.0661	HM

5.D.1 The Total Manufacturing Sector

Important conclusions which emerge from Tables 5.12, 5.13, 5.14 and 5.15 regarding the total manufacturing industry are as follows:

(1) Demand for each input is inelastic. In particular, demand for renewable and non-renewable resources are the most inelastic indicating that demand for resource inputs are less responsive to changes in their own prices. The own price elasticities of demand for energy, renewable and non-renewable resources are -0.41, -0.08 and -0.04 respectively.

(2) Energy and labour are substitutes (the estimate of σ_{LE} is about 0.601), cross price elasticities for energy and labour η_{LE} and η_{EL} are 0.02 and 0.24 respectively.

(3) Renewable resources and labour are substitutes (σ_{LR} is 0.38) while non-renewable resource and labour are complements (σ_{LNR} is -0.12). The estimated cross elasticities η_{LR} and η_{NRL} are 0.07 and -0.03 respectively, the cross elasticities η_{LNR} and η_{NRL} are -0.03 and -0.05, respectively.

(4) Energy and capital are complements, σ_{KE} is -0.19 while the cross price elasticities, η_{KE} and η_{EK}, are -0.01 and -0.03 respectively.

(5) The parameters σ_{LR}, σ_{LNR}, σ_{KR}, σ_{KNR}, σ_{ER} and σ_{ENR} behave differently than those of σ_{LM}, σ_{KM} and σ_{EM} in previous studies. A comparison between σ_{iM} (i=L, K, E) and σ_{ij} (i=L, K, E j=R, NR) will be made in following section.

(6) Renewable and non-renewable resources show some substitutability. The estimated value of σ_{RNR} is 0.07, while η_{RNR} and η_{NRR} are 0.014 and 0.012 respectively.

5.D.1.1 Implications of the Results

Since labour and energy alone are substitutes an increase in the price of energy alone may lead to greater use of labour (labour intensiveness).[16] A positive value of σ_{LR} indicates an increase in the price of renewable resources may also have a positive influence on employment. On the other hand, a negative value of σ_{KE} (capital-energy complementarity) implies that an increase in the price of energy may lead to a smaller capital stock.

A positive value of σ_{ER} means that firms substitute renewable resources for non-renewable energy resources and that given an increase in the price of energy (the price of renewable resources remaining constant) a firm may substitute renewable resources for energy. A positive value of σ_{RNR} also has similar implications. It is worth noting that the magnitutes of σ_{ER} (0.25) and σ_{RNR} (0.07) are somewhat different and indicates that renewable resources are more sensitive to energy price increases than non-renewable resources.

In a similar way, conclusions can also be drawn about changes in the price of other inputs.

5.D.1.2 A Comparison of Total Manufacturing Results With Previous Studies

A comparison of results from other U.S. and Canadian studies and the present study are shown in Table 5.16 below. In their U.S. manufacturing study Berndt and Wood (1975) found that materials are substitutable with K, L and E, whereas this study finds that renewable resources are substitutes for labour, complementary to capital and substitutes for energy; non-renewable resources are complementary to labour, substitutes for capital and also substitutes for energy. Labour-energy substitutability is exactly the same in both the studies, whereas capital-energy complementarity is quite different in magnitude (row 5, Table 5.16).

TABLE 5. 16

ELASTICITIES OF SUBSTITUTION IN TOTAL MANUFACTURING

	U.S. STUDY	CANADIAN STUDIES			
	Berndt and Wood (1975)	McRae[1] (1978)	Denny et al (1978)	Denny and May	Present Study
σLE	0.61	1.80	4.89		0.61
σLM	0.57	-.17	0.43	1.24	
σLR					0.38
σLNR					-0.12
σKE	-3.09	1.60	-11.91		-0.19
σKM	0.58	1.30	-0.99		
σKR					- .53
σKNR					0.29
σEM	0.76	-.10	0.12		
σER					0.25
σENR					0.75

Evaluated at the mean value, except Denny and may 1978 (at 1972 value)
1. Ontario Manufacturing

It can also be seen in Table 5.16 that the value of σ_{EM} in the U.S. study is very close to the value of σ_{ENR} in the present study, but the value of σ_{ER} is about one third of the value of σ_{EM} and of σ_{ENR}.

It can be noted that the aggregate elasticity of substitution between labour and materials from the U.S. study is positive and is somewhat different from the disaggregated elasticity of substitution parameters in this study (σ_{LR} is positive and σ_{LNR} is negative).

Own price elasticities of demand for L, K and E estimated in this study are similar to those found in the U.S. study (Table 5.17). However, the U.S. value of η_{MM} is substantially larger than both η_{RR} and η_{NRNR} as estimated in this study.

5.17

COMPARISON OF OWN PRICE ELASTICITIES OF DEMAND IN TOTAL MANUFACTURING

	U.S. STUDY	CANADIAN STUDIES				
	Berndt and Wood (1975)	McRae[1] (1978)	Fuss (1977)	Denny et al	Denny[2] & May	Present Study
LL	-0.45	-.20	-0.49	-0.77	-0.75	-0.32
KK	-0.44	-1.06	-0.76	-0.31	-1.10	-0.53
EE	-0.49	-0.64	-0.49	-0.59		-0.41
MM	-0.24	-0.23	-0.36	-0.05	-0.50	
RR						-0.08
NRNR						-0.04

1. Ontario Manufacturing
2. 3 Input Model

A comparison of cross price elasticities of demand between studies are shown in Table 5.18. It can be seen that η_{LE} and η_{EL} are similar in both studies while η_{LM} and η_{ML} have the same sign as η_{LR} and η_{RL} but differ in magnitudes. η_{LNR} and η_{NRL} , however, differ from η_{LM} and η_{ML} both in sign and magnitude between studies.

The similarity and dissimilarity of the results is noteworthy. The U.S. study shows that η_{LM} is positive whereas if η_{LM} is disaggregated into η_{LR} and η_{LNR} as in this study they are not both positive. This shows that elasticities of demand for resources remain unknown (mixed) if R and NR are not separated. A similar phenomenon can also be observed in the cases of η_{KM} and (η_{KR} , η_{KNR}) and η_{EM} and (η_{ER}, η_{ENR}).

TABLE 5.18

COMPARISON OF CROSS ELASTICITIES OF DEMAND IN TOTAL MANUFACTURING

η_{ij}	U.S. STUDY Berndt and Wood (1975)	CANADIAN STUDIES McRae[1]	Fuss	Present Study
η_{LE}	0.03	0.03	0.04	0.02
η_{EL}	0.20	0.37	0.05	0.24
η_{LM}	0.37	-0.10	0.25	
η_{ML}	0.18	-0.04	0.11	
η_{LR}				0.07
η_{RL}				0.15
η_{LNR}				-0.03
η_{NRL}				-0.05
η_{KE}	-0.16	0.02	-0.05	-0.01
η_{EK}	-0.17	0.33	-0.004	-0.03
η_{KM}	0.30	0.75	0.56	
η_{MK}	0.02	0.27	0.25	
η_{KR}				-0.10
η_{RK}				-0.10
η_{KNR}				0.06
η_{NRK}				0.05
η_{EM}	0.46	-0.06	-0.02	
η_{ME}	0.03	0.00	-0.0006	
η_{ER}				0.04
η_{RE}				0.01
η_{ENR}				0.16
η_{NRE}				0.03

1. Ontario Manufacturing

In comparing the results of the present study with the earlier Canadian studies it should be noted that those earlier studies are not directly comparable to this study. The reason is that those studies either utilize different flexible cost functions or are based on different data. For example, the Denny et al. (1978) study is based on the Generalized Leontief cost function, the McRae (1978) study is based on Ontario manufacturing data and Denny and May's study is based on a three input (K, L, M) model.

It can be seen in Table 5.16 above that the differences between the estimated elasticities of substitution of the present study and the earlier Canadian studies are considerable but there are also substantial differences among them. However, the estimated own elasticities of demand are not so different. In particular, in Table 5.17, the results of Fuss (1977), Denny et al. (1978) and that of the present study are compared.

Cross price elasticitie in Table 5.18 shows that some of the estimated cross elasticities of the earlier studies are also reasonably close (e.g., η_{LE} , η_{EL} and even η_{EK}) while the dissimilarities in other cases are not unlikely due to the differences in specification of the model and the use of a different data set.

5.D.2 The Food and Beverages Industry

The food industry is one of the most renewable resource intensive industries. It is also an industry which is important in all provinces (see Table 3, Appendix 2).

Consequently, this sector is a useful for illustration of the results for manufacturing at the two-digit level. Important observations from Tables 5.12, 5.13, 5.14 and 5.15 regarding the food and beverages industry are as follows:

(1) Input demands are all inelastic to changes in their prices. The own price elasticity of demand for E and R are most inelastic. The inelastic demand for renewable resources is as expected for the food industry since this is a resource intensive industry.

(2) The elasticity of demand for NR is absolutely larger than for other inputs since NR is not as important as R.

(3) Energy and labour are substitutes, the estimated value of η_{LE} is 0.69, while η_{LE} and η_{EL} are 0.013 and 0.193 respectively.

(4) Labour-renewable resource and labour-non-renewable resources are both substitutes, but non-renewable resources show a higher degree of substitutability. η_{LR} and η_{RL} are 0.28 and 0.14 respectively, while η_{LNR} and η_{NRL} are 0.06 ana 1.13 respectively. η_{NRL} is elastic.

(5) Energy and capital are substitutes which is consistent with McRae (1978) and Denny et al. (1979). The estimated σKE is 1.07, while estimates of η_{KE} and η_{EK} are 0.02 and 0.15 respectively .

(6) Unlike materials, the elasticities of substitution of R and NR with other inputs vary. The signs of the elasticities are also quite different.

(7) The value of σ_{ER} indicates substitutability. However, σ_{RNR} indicates complementarity implying that both resources are used together. This is contrary to what has been found in the case of total manufacturing.

5.D.2.1 Implication of the Results

Some of the important implications of these results are as follows:

Since σ_{LE} is positive in the non-homothetic case, an increase in the price of energy may increase the intensity of labour use. Increases in the prices of R or NR may also result in additional labour intensiveness.

Since σ_{KE} is positive an increase in P_E may induce capital intensity. Similarly, a positive σ_{KNR} (1.8033) implies that increases in P_{NR} may increase the use of capital, while a negative σ_{KR} (-0.15) indicates that increases in P_R may reduce capital intensity.

A negative σ_{ENR} indicates that an increase in P_{NR} may slow down energy consumption.

It should be noted that results obtained from a homothetic and a non-homothetic model provides different conclusions. For example, for the food industry, the estimated σ_{LE} obtained from the homothetic model indicates that energy price increases may reduce employment, while the estimated σ_{LE} obtained from the non-homothetic model indicates that energy price increases may induce employment. However, on the basis of our test results presented in section C of this chapter, we accept the non-homothetic

model and as such we rely on the positive value of σ_{LE}.

5.D.2.2 A Comparison of the Food Manufacturing Results with the Previous Studies

In comparing our food manufacturing results with those of a U.S. and other Canadian studies, we have to keep in mind that the U.S. study is a three input cross section analysis and the Canadian studies use only Ontario manufacturing data (see Tables 5.19, 5.20 and 5.21).

It can be seen in Table 5.19 that for the U.S. case σ_{LN} denotes substitutability. For the Canadian case we also find σ_{LR} and σ_{LNR} to be substitutes and these values bracket the Humphrey-Moroney value for resources. However, in the U.S. case σ_{KN} is positive (0.64) while in our case σ_{KR} is negative (-0.15) and σ_{KNR} is positive (1.80); the case of weak complementarity and strong substitutability respectively.

As can be seen in Table 5.19 our estimated elasticity of substitution parameters differ considerably from those of McRae (1978). These differences are not unlikely given that the studies differ both in data (Ontario vs Canadian) as well as specification and time period.

TABLE 5.19

COMPARISON OF ELASTICITES OF SUBSTITUTION IN THE FOOD INDUSTRY

	U.S. STUDY	CANADIAN STUDIES	
	Humphrey-Moroney (1975)	McRae[1] (1978)	Present Study
σLE		-2.64	0.70
σLM		-0.24	
σLR			0.14
σLNR			3.39
σLN*	0.64		
σKE		1.76	1.07
σKM		0.23	
σKR			-0.15
σKNR			1.80
σKN*	0.64		
σEM		0.05	
σER			0.42
σENR			-30.13

*Where
σLN: Elasticity of substitution between labour and natural resources

σKN: Elasticity of substitution between capital and natural resources.

1. Ontario food manufacturing

We now turn to a comparison of our price elasticities. It can be seen in Table 5.20 that our $|\eta_{LL}|$ is greater than our $|\eta_{KK}|$,just the reverse of the results of others. Also their η_{MM} differs considerably from our η_{RR} and η_{NRNR} but also among themselves.

A comparison of the cross price elasticities are shown in Table 5.21. The similarities and dissimilarities of our results with other Canadian studies can be observed in this table. It can be noted that our η_{KE} is the same as that of McRae's. It can be seen that R and NR behave differently with respect to M, otherwise results are comparable.

TABLE 5.20

COMPARISON OF OWN PRICE ELASTICITIES OF DEMAND IN THE FOOD INDUSTRY

	CANADIAN STUDIES			
	McRae[1] (1978)	Fuss[2] (1975)	Denny et al.(1979)	Present Study
η LL	-0.29	-0.38	-0.27	-.28
η KK	-0.52	-0.70	-0.74	-.27
η EE	-0.04	0.00	-0.13	-.13
η MM	-0.01	-0.28	-0.16	
η RR				-.03
η NRNR				-.51

1. Ontario Manufacturing
2. 3 Input Model

TABLE 5.21

COMPARISON OF CROSS PRICE ELASTICITIES OF DEMAND IN THE FOOD INDUSTRY

	McRae[1] (1978)	Fuss[2] (1975)	Denny et al (1979)	Present Study NH[3]	HM[4]
LE	-0.03	0.00	-0.006	0.013	-0.001
EL	-0.35	0.00	-0.070	0.193	-0.016
LM	-0.16	0.22	-0.030		
ML	-0.04	0.06	-0.007		
LR				0.080	0.27
RL				0.039	0.13
LNR				0.049	0.06
NRL				0.940	1.13
KE	0.02	0.00	0.005	0.202	0.02
EK	0.35	0.00	0.091	0.134	0.14
EM	0.15	0.58	0.524		
MK	0.04	0.22	0.162		
KR				-0.082	-0.17
RK				-0.018	-0.04
RNR				0.026	0.03
NRK				0.226	0.29
EM	0.03	0.00	0.108		
ME	0.00	0.00	0.002		
ER				0.238	0.36
RE				0.008	0.01
ENR				-0.435	-0.41
NRE				-0.556	-0.52

1. Ontario Manufacturing
2. Uses a two-stage model
3. Non-homothetic model
4. Homothetic model

It may be seen from the above results that like primary factors of production (L, K), resources are also important factor inputs in that they are responsive to price changes (as can be seen from the elasticities of factor demand) and can be substitutes or complements. Therefore, the estimated elasticity parameters $\hat{\sigma}_{ij}$ (i=L, K and j=E, R, NR), $\hat{\eta}_{ij}$ (i=L, K and j=E, R, NR), $\hat{\eta}_{ij}$ (i=L, K and j=E, R, NR), in addition to those related to the primary factor inputs, obtained in this study can be useful in analyzing the effects of changes in the price of inputs, in particular, the changes in the prices of E, R and NR on input use. The following section explores in more detail the implications of these estimated elasticities across industries including the total manufacturing sector.

5.D.3 The General Features of Empirical Results Across Industries

Summary statistics of the factor demand model are reported in the previous section, in Tables 5.12, 5.13, 5.14 and 5.15 respectively. Usually the results of the non-homothetic translog cost functions are reported since the previous analysis (section 5.C) showed that it was usually the appropriate model (except for the leather, furniture and chemicals industries).[17] However, it has been found that in other cases (textiles, clothing, printing, metal fabricating, transportation, electrical products, machinery, non-metallic and miscellenous industries) the non-homothetic model, although accepted by the homotheticity

tests, does not always simultaneously satisfy both economic and mathematical conditions.[18] Therefore, in those cases the estimates of the parameters reported are based on the homothetic model which does not have this problem.

5.D.3.1 Price Elasticities

Own and cross elasticities of demand are valuable for interpreting the effects of policy decisions and exogenous events on the use of inputs. The following features of the elasticities determined in this study are worth noting.

(1) There are substantial differences in price elasticities for all inputs across two-digit industries. For example, the price elasticity of energy input is mostly inelastic across industries but it can also be elastic (e.g., furniture and miscellaneous industries) and ranges from -0.016 to -1.540. Similar differences can also be observed for other inputs across industries but neither L or K has an elasticity greater than unity. Therefore, changes in the price of an input affects different industries' production decisions to widely varying degrees.

(2) There is a substantial difference between the total manufacturing sector and individual two-digit industries in terms of magnitudes of the own and cross price elasticities and in terms of the signs of cross price elasticities between several inputs.

(3) Own price elasticities are inelastic except in a few instances, namely, textiles (NR), furniture (E), miscellaneous (E) and wood (NR). Similarly, inelasticity is

almost always the rule for cross price elasticities.

The diversity of the two-digit industry results indicates the desirability of undertaking a study at the disaggregated level rather than relying upon results for total manufacturing. For specific industries, what is found at the aggregate level is not necessarily true at the disaggregated level and can often be quite misleading (refer to Tables 5.12, 5.13, 5.14 and 5.15).[19]

5.D.3.2 Elasticities of Substitution

The cross elasticities of substitution σ_{ij} between inputs i and j are shown in Table 5.15. Table 5.22 below summarizes the number of cases of substitutability and complementarity of σ_{ij} across industries including total manufacturing.

TABLE 5.22

THE NUMBER OF CASES OF SUBSTITUTABILITY AND COMPLIMENTARITY BETWEEN INPUTS ACROSS INDUSTRIES[a]

	Substitutes	Compliments	Total Number Of Cases
σLK	20	1	21
σLE	21	0	21
σKE	6	15	21
σLR	10	2	12
σKR	7	5	12
σLNR	12	5	17
σKNR	12	5	17
σER	11	1	12
σENR	10	7	17
σRNR	4	5	9

a: As indicated by the sign of the elasticity of substitution (σ_{ij})

It can be seen in Table 5.22 that labour and capital are substitutes for all industries except one, the petroleum and coal products industry. The very fact that they are complements as opposed to substitutes is due to the nature of the production technology. Petroleum refining, for example, requires a specific technology and affords little possibility of substitution between labour and capital.[20] That is, some specific amount of capital and labour are required for the production of a given amount of oil, gas or coal.

The elasticity of substitution between labour and energy σ_{LE} denotes substitutability for all industries with differences in magnitudes ranging from 0.04 to 2.62. The value of σ_{LE} is the lowest in the case of electrical products and highest in the case of petroleum and coal products. A relatively higher degree of substitutability can be observed in other cases such as the tobacco, rubber and knitting industries. Positivity of σ_{LE} for all industries suggests that energy price increase may increase labour intensity in the Canadian manufacturing sector.

σKE: Capital-energy complementarity ($\sigma KE<0$) is not a general result but most previous studies support this hypothesis.[21] On the other hand, contrary evidence is reported by Griffin and Gregory (1976) and Pindyck (1977), based on a three input model (capital, labour, energy) using time series data for manufacturing pooled by the Organization for Economic Cooperation and Development (OECD)

countries; Halvorson and Ford (see Berndt and Wood, 1979), based on cross-section data on capital, two types of labour and three types of energy by state for eight two-digit SIC manufacturing industries; Ohta (1975), based on data from U.S. electric utility purchases and energy efficiency characteristics of boilers and turbogenerators, and using a hedonic approach; McRae (1978), based on a regional KLEM model specification.

This conflicting evidence might be due to the fact that the results are based on different sets of data, different time periods, different methods of estimation and different approches to measuring inputs. It may be noted that the measurement problem might be a crucial reason for the contradictory evidence. For example, Berndt and Wood (1979) point out that the residual measure of capital by Griffin and Gregory might be one of the main reasons for the contrary results since there are many problems with such a measure. As a residual measure the return to capital equipment and structures,

> "... captures many unidentified factors such as returns to land, inventories, economic rent, working capital, indirect business taxes and any error in the measurement of value added or the wage bill" (Berndt and Wood,1979, p. 352).[22]

The implication of capital-energy complementarity is that given higher energy prices, demand for investment may

decline. Capital-energy substitutability, on the other hand, would imply that higher energy prices may induce capital intensity. In this study σKE complementarity has been found in 15 out of 21 cases (including total manufacturing). The magnitudes of the negative σKE varies from -0.19 (total manufacturing) to -4.41 (furniture), while the positive σKE ranges from 0.07 (leather) to 9.22 (miscelleneous). A relatively higher complementarity can be noted in the cases of rubber, textiles, metal fabricating, machinery, electrical products and petroleum industries. While we offer no explanation, we note that for most of the renewable intensive industries (food, wood, paper) σKE denotes substitutability and for all non-renewable resource intensive industries σKE are complements.

σLR: Renewable resources are used in 12 out of 21 industries. Labour and renewable resources are substitutes in most cases (exception, textiles and chemicals). The reason for these exceptional cases may be due to the nature of the industries and the technological constraints[23] faced by them. Labour-renewable resource substitutability in the majority of cases indicates that like σLE substitutability, an increase in the price of renewable resources may lead to labour intensity in those industries. The magnitude of positive σLR varies from 0.14 (tobacco) to 2.78 (transportation). We also note that for all resource intensive industries σLR indicates substitutability.

σKR: Out of the 12 industries, renewable resources and capital are found to be complements in 5 cases and substitutes in the others. A complementary relationship has industry specific implications. Industries for which σKR is negative are food, tobacco, furniture, transportation and total manufacturing. As to the role of renewable resource intensity on the σKR complementarity or substitutability we cannot draw any definite conclusions, since of the five resource intense cases, σKR indicates complementarity in three cases (food, tobacco and total manufacturing) and substitutability in two cases (wood and paper). There are also substantial variations in the magnitude of σKR across industries. For example, for the clothing industry σKR is about 0.02 while for the textiles and miscellaneous this value is about 4.35 and 4.86 respectively.

σLNR: In the majority of the cases (12 out of 17) labour and non-renewable resources are substitutes ($\sigma LNR>0$). A higher degree of substitutability is usually observed in the cases of two-digit level renewable resource intense industries (food, wood and paper). It can also be seen that in the few cases (rubber, textiles, printing, primary and total manufacturing) exhibiting labour-non-renewable resource complementarities, σLNR has small (absolute) values. Therefore, it may be concluded that like E and R, an increase in the price of NR may also induce labour intensity in most of the Canadian manufacturing industries.

σKNR: Capital is a substitute for non-renewable resource (σKNR 0) in 12 out of 17 cases. It is important to note that for some of the non-renewable resource intense industries (metal fabricating and electrical products) σKNR denotes complementarity. Even in the cases of other non-renewable resource intense industries (primary, petroleum and total manufacturing) σKNR substitutability is not statistically significant at the 5% level.

σER: Energy and renewable resources display substitutability in most cases (except for the paper industry). Energy-resource complementarity in the case of the paper industry is hardly surprising given its technology. It is also important to note that paper is one of the most energy and resource intensive industries. However, positiveness of σER indicates that firms substitute relatively cheaper renewable resources for relatively expensive energy resources. This seems to happen considerably in the cases of textiles, transportation, chemicals and miscellaneous industries.

σENR: Energy and non-renewable resources are substitutes in 10 out of 17 cases in which non-renewable resources are used as inputs. Therefore, general conclusions cannot be drawn. The substitutability or complementarity of σENR parameters depends on the industry in question. In particular, σENR seems to have displayed substitutability in the cases of non-renewable resource intensive industries (primary, metal fabricating, electrical

products and total manufacturing) with the exception of petroleum industry in which case σENR complementarity is also statistically insignificant.

σRNR: Both R and NR are used simultaneously as inputs in nine out of 21 cases but usually one or the other is a small component. We find that RNR are complements in five out of nine cases. In the cases of textiles and chemicals estimates of RNR are very high in magnitude while in the case of food industry this is very small in magnitude. One of the reasons for such results may be that these are not non-renewable resource intense industries, the percentage shares of NR by these industries being very small (e.g., food 1.4%, textiles 0.44%, chemicals 6.4%).

It is important to note from the above analysis that the use pattern of E and NR is different across industries with respect to policy implications, even though both are largely non-renewable resources. We have seen that σRNR behave quite differently than σER. In the case of σER, we have concluded that firms substitute R for E. However, we cannot make such a conclusion in the case of σRNR since in the majority of cases it denotes complementarity. Similarly, considering σKE and σKNR it can be seen that σKE are complements in 15 out of 21 cases, whereas σKNR are complements in five out of 17 cases.

Finally, as to the behaviour of the resource intense industries we note that of the non-renewable resource intense industries the petroleum industry is an exceptional

case in more than one way. For example, for this industry σENR indicates complementariy whereas for all other non-renewable resource intense industries this denotes substitutability. Again σLK is positive for all industries except the petroleum industry; also σKNR are substitutes for petroleum and primary while it is complementary for other non-renewable resource intense industries (metal fabricating, machinery and electrical products).

Similarly, as mentioned before, the paper industry also behaves exceptionally in that σER denotes complementarity for this industry while it denotes substitutability for others.

5.D.3.3 Cross Elasticities of Factor Demand

The cross price elasticities of factor demand ηij with respect to changes in prices of K, E, R and NR respectively are shown in Table 5.13. The cross price elasticities with respect to changes in prices of L, K, E and NR are shown in Table 5.14. The sign of both ηij and ηji are determined by σij discussed in the previous section.[24]

Note that in Table 5.13 the ηij are all inelastic (with the exception of chemicals) and they differ substantially across industries. For instance ηLE ranges from 0.0005 (electrical products) to 0.05 (primary metal industry), ηKE from -0.07 (furniture) to 0.14 (miscelleneous), ηER from -0.54 (paper) to 0.35 (wood). Similar variations can also be observed in the case of other cross elasticities across industries.

This wide range of elasticity values imply diverse impacts of price changes on different industries. For example, if the price of energy increases by 10%, the demand for labour in the primary metal industry may increase by 0.5% whereas a similar increase in the price of energy the demand for labour in the electrical products industry may increase only by 0.005%. Similar variations can be noted for other ηij across industries. However, in evaluating these effects we must keep in mind that these elasticities are dependent on input cost shares and as such the predicted effects of a change in input price will be partly determined by the importance of its cost share in the total cost of production. For example, in the above case, the primary metal industry is an energy intense industry whereas the electrical products is not and their average cost shares are 0.06 and 0.01 respectively. Accordingly σLE for the primary metal industry is larger than for electrical products industry.

Note in Table 5.14 the ηji are not all inelastic--ηKL (furniture, miscellaneous), ηEL (knitting), ηRL (transportation), ηNRL (food, wood), ηRK (textiles, transportation), ηRE (chemicals), ηNRR (textiles, paper)--but they differ considerably across industries. For example, ηKL varies from -0.196 (petroleum) to 1.096 (miscellaneous), ηEL from 0.025 (electrical products) to 1.111 (knitting), ηRE from -0.21 (paper) to 1.38 (chemicals). Similar variations can also be noted in other

cases of ηji across industries. It should be noted that each column in Table 5.14 corresponds to each column in Table 5.13 differing only by the fact that the columns in Table 5.14 are the reversed cross price effects.

It can be seen in Table 5.14 that in some cases (e.g. ηKL, ηEL, ηNRL, ηEK, ηNRK, ηNRE, ηNRR) increases in the price of the i-th input may result in relatively higher impact on demands for the j-th input than in the reverse case in Table 5.13. For example, ηLK for the wood industry in Table 5.13 is 0.03, whereas ηKL in Table 5.14 for this industry is 0.10; for the same industry ηLE is 0.01 in Table 5.13 and ηEL is 0.30 in Table 5.14. Similarly, for the paper industry ηKNR is 0.02 in Table 5.13, while ηNRL is 0.34 in Table 5.14; for the same industry ηKE in Table 5.13 is 0.03 and ηEK in Table 5.14 is 0.095. Similar differences can also be observed in other cases. The reason is due to the higher relative cost share of the i-th input whose price increase may cause the effect on the j-th input. For example, consider ηEL for the wood industry, the shares of E and L for this industry are 0.39 and 0.02 respectively and therefore, ηEL is determined by a larger share than ηLE.[25] A similar explanation holds for other cases.

5.E Summary

Finally, the overall implications of the estimated elasticities of subsitution and elasticities of demand can be summarized as follows:

(1) Estimates of elasticities of substitution clearly imply that increases in the price of energy or resources, other things remaining constant, is very likely to increase the demand for employment with only a few exceptions.

(2) The impact of increases in the price of energy, on the other hand, is likely to reduce capital intensity. Similarly, increases in the price of capital is more likely to reduce the demand for energy. Therefore, if energy conservation is the objective, the policy of an investment tax credit which reduces the price of capital, may not be a preferred policy since this may induce energy consumption.

(3) Substitutability between E and R in most cases implies that the increased use of renewable resources may ease the pressures on energy demand. However, we have to keep in mind that one of the resource intense industries (paper) implies a very special case of σER complementarity and also that the degree of substitutability in the other renewable resource intense industries is usually not great (e.g., food 0.25, tobacco 0.09, total manufacturing 0.25 and wood 0.75).

(4) The behavioural implications of the two non-renewable resources (E and NR) are quite distinct (e.g. σER denotes substitutability in the majority of the cases whereas σNRR denotes complementarity in many cases). Re-enforced by the fact that renewable resources and non-renewable resources are also different, this argues in favour of the separate treatment of R and NR.

(5) Own elasticities of factor demand indicate that like labour and capital, energy, renewable and non-renewable resources respond to own price changes with elasticities usually varying from 0 to -1.0.

(7) With respect to cross elasticities ηLK, ηKL, ηLE, and ηEL are almost always positive, ηKE, ηEK are usually negative and in the other cases signs vary.

Footnotes to Chapter 5

1. For a detailed discussion of the Divisia index aggregator see Chapter 3.

2. Depending on whether an industry uses R or NR or both, it can be seen that for some of the industries there are four inputs (using either R or NR) and for some five inputs (using both R and NR).

3. The rental price of capital is calculated by using the formula as adopted by Berndt (1979). For details see section A.1.b of Appendix 1.

4. For example, according to Denny and Fuss (1977), the condition for the separability of X_1, and X_2 from X_3 is given by $\alpha_1/\alpha_2=\beta_{13}/\beta_{23}$. They point out that this implies a flexible technology and the additional restriction $\beta_{11}\beta_{22}=\beta_{12}^2$ implies an exact form of the translog function. See footnote 12, p. 408, Denny and Fuss (1977).

5. In our case the separability of X_1 and X_2 from X_3 can be obtained from the restrictions in (48, Chapter 2) as

$\beta_{13}=\alpha_1\rho_3$

$\beta_{23}=\alpha_2\rho_3$

which implies $\alpha_1/\alpha_2=\beta_{13}/\beta_{23}$, and is the weak separability condition of Denny and Fuss (1977). Since we adopt the approximate form of the translog, the additional condition $\beta_{11}\beta_{22}=(\beta_{12})^2$ (noted in the previous footnote) is not imposed. For further discussion see Laumas and Williams (1981), p. 328 and Denny and Fuss (1977).

6. In some cases the non-linear least squares program (in TSP package) did not converge even at a weaker convergence criterion. The IZE technique, on the other hand, provided by a user written APL language program worked quite well. The reason seems to be that TSP (1973 version) runs with single precision, while APL runs with double precision.

7. For total manufacturing, strong homotheticity is decisively rejected, while weak homotheticity is marginally accepted, therefore, in the empirical analysis, we retain the non-homothetic model. Pindyck (1979, p.174) found the results for homotheticity tests inconclusive on data from the United States and Canada. However, Denny and May (1978, Production Economics, volume 2, p. 61) decisively rejected strong homotheticity.

8. Some of the previous studies, (e.g. studies by Binswanger, (1974a) , Binswanger (1974b), Berndt and Wood (1975)) assume a constant returns to scale specification.

9. This raises the question of ommission of variables which in turn implies bias in the estimated parameters.

10. The tobacco industry is also one of the renewable resource based industries. Since none of our selected non-renewable resource components are used by this industry, the industry is not mentioned here in the list of renewable resource intense industries for testing this hypothesis (separability of R from NR).

11. Humphrey and Moroney (1975, p.72) noted that the translog production model cannot fruitfully be applied in these sectors that make only minor use of natural resource products. Although energy shares are usually quite small, sometimes these resource shares are even smaller (e.g. textiles and transportation; see Table 5.1 above).

12. Tests of hypotheses concerning homotheticity indicate that for most of the industries the non-homothetic specification is the appropriate one. However, failures of the non-homothetic version to satisfy other fundamental conditions for some industries required resorting to the homothetic version in those cases. See Section 5.D.3 for further discussion

13. See, for example, Binswanger (1974) and Pindyck (1979).

14. Treating Si and Sj as stochastic variables it is possible to approximate the standard error of σij with the following method (see Johnston, 1972, pp. 401-402). In matrix notation, the standard error (S.E.) of σij can be written as :

$$\text{S.E.}\ (\sigma ij)=\sqrt{\text{Var}(f)}$$

where $f=\sigma ij=f(\beta ij,\ Si,\ Sj)$

and the asymptotic variance of f is given by

$$\text{Var}(f)=\frac{1}{n}\left(\frac{\partial f}{\partial \hat{\alpha}}\right)' V \left(\frac{\partial f}{\partial \hat{\alpha}}\right),$$

where $\alpha=(\beta ij,\ Si,\ Sj)$

$$\frac{\partial f}{\partial \hat{\alpha}} = \begin{bmatrix} \left.\frac{\partial f}{\partial \beta_{ij}}\right| \beta_{ij} = \hat{\beta}_{ij} \\ \left.\frac{\partial f}{\partial s_i}\right| s_i = \hat{s}_i \\ \left.\frac{\partial f}{\partial s_j}\right| s_j = \hat{s}_j \end{bmatrix}$$

and V is the estimated variance-covariance matrix given by

$$V=\begin{bmatrix} Var(\hat{\beta}ij) & Cov(\hat{\beta}ij\ \hat{S}i) & Cov(\hat{\beta}ij\ \hat{S}j) \\ Cov(\hat{S}i\ \hat{\beta}ij) & Var(\hat{S}i) & Cov(\hat{S}i\ \hat{S}j) \\ Cov(\hat{S}j\ \hat{\beta}ij) & Cov(\hat{S}i\ \hat{S}j) & Var(\hat{S}j) \end{bmatrix}$$

15. Problems arise in the cases of some of the industries (primary, machinery, petroleum, chemicals and metal fabricating) in that estimates obtained using the whole sample period 1961-76 provide estimated positive values of own elasticity of factor demand. It was noted that in those cases at least one of the observations --e.g. primary, price of capital (1965, 1968); machinery, price of capital (1976); metal fabricating, price of capital (1974); petroleum , price of resources (1975, 1976); chemicals, price of energy (1976)-- were unusually large in these years. However, estimates based on excluding those observations provide negative values of own elasticity of demand. Therefore, for those industries reported results are based on excluding those observations.

16. In evaluating the results we assume that the output effect is held constant and as such we must be cautious in making strong statements.

17. In the case of the leather industry reported results are based on the non-homothetic model instead of the homothetic model. This is because the estimates obtained from the non-homothetic model satisfy all the concavity conditions whereas those of the homothetic model do not.

18. These conditions are the negativity of the own price elasticities of demand and the concavity of the cost function (i.e. the negative semi-definiteness of the Hessian matrix).

19. Another Canadian study of similar type by Cameron and Schwartz (1979) focuses on the uneven impact or greater difficulty with respect to adjustment among disaggregated industries. They identify that combination of high shares and low elasticity creates problem in adjustment.

20. This implies a technological constraint. The petroleum refining is a chemical process and we expect that such an activity would use some fixed amount of capital and labour. Moreover, this is a capital intensive industry and there might be a lack of adjustment in response to sharp (unusual) increase in the price of non-renewable resources (e.g. crude mineral oils).

21. See Berndt and Wood (1979).

22. Berndt and Woods (1979) also attribute observed differences in σKE to the failure to distinguish between net and gross substitution effects.

23. As determined by the production technology.

24. It can be noted that $\eta_{ij}=\sigma_{ij}S_j$ and $\eta_{ji}= \sigma_{ij}S_i$, indicating that η_{ij} is determined by σ_{ij} and S_j, whereas η_{ji} is determined by the same σ_{ij} but with S_i instead of S_j. Since S_i and S_j are both positive the sign of η_{ij} and η_{ji} depend on the sign of σ_{ij}.

25. It follows from footnote 18.

Chapter 6. Productivity Analysis

Productivity is the relationship between outputs of goods and services and the inputs of basic resources; labour, capital, energy and natural resources.[1] In the simplest terms this relationship can be expressed as the ratio of aggregate output to any particular input or to the index of aggregate inputs. In other words, this is the index of output per unit of input (e.g. output per man-hour) or aggregate inputs.

Increases in productivity can be accomplished through induced innovation, technological progress, economies of scale, economies of scope and learning-by-doing. An increase in productivity results in savings of scarce resources. The increase in productivity is particularly important in the case of scarce non-renewable resources such as energy. Changes in productivity among firms or industries may indicate a shift in their relative competitive positions. Productivity changes may also be a valuable policy tool for governments which are regulating firms according to a "fair return" criterion in that it may assist in identifying (and penalyzing) firms with poor productivity performance.

Because productivity growth rates are an important economic indicator, there has been renewed interest in the subject which has resulted in many studies of Canadian

manufacturing being undertaken.[2] Since none of the studies are concerned with natural resources as separately identified inputs, the present study will investigate the impact of resources on productivity growth rates and in particular how effectively these resources are utilized in manufacturing production.

There are alternative productivity measures. In the following section we discuss partial and total factor productivity (PFP and TFP). Partial measures are rejected and so the empirical results are only reported for total factor productivity. These results are compared with similar estimates from other studies. However, the conventional residual approach to total factor productivity measurement assumes constant returns to scale. This assumption was generally rejected in Chapter 5. Therefore, unlike other studies, we also determine parametric total factor productivity measures and scale elasticities for the total manufacturing sector which are consistent with the estimated non-homothetic cost function.

6.A.1 Partial versus Total Factor Productivity

Average productivity is the ratio of real output to real factor input. If Q_t is the index of real output at time t and X_t is the index of a real input at time t, average factor productivity of X_t is defined as

$$P_{xt}=Q_t/X_t \qquad (1)$$

The reciprocal of P_{xt} is the input requirement per unit of output or the intensity of the input. Since the average

productivity measures output per unit of a single input, it is also known and better described as Partial Factor Productivity (PFP).

Because output is produced by a combination of inputs, an appropriate measure of total factor productivity will take into account all inputs. The productivity measure obtained this way is known as Total Factor Productivity (TFP) and is defined as

$$Pv_t = Q_t / F_t \qquad (2)$$

where F_t is the index of total inputs.

6.A.2 Limitations of PFP

The limitations of PFP measures are the following; (a) no causal meaning can be asigned to PFP, and (b) the efficient use of a particular input depends on other inputs, but this is not accounted for in the measure (see Dhruvarajan, et al., 1978).

Although PFP is subject to limitations, factor intensity or the reciprocal of PFP can be interpreted as an input requirement per unit of output. In fact, factor intensity can be used as an indicator of factor use, and the trend of factor use over time can be used for analytical purposes.

Berndt (1978) has shown that the effect of price variation on average input productivity (PFP) can be summarized succinctly by the negative of the price elasticity of demand, and as such can be used as an alternative to PFP. If η_{ij} is the price elasticity of the

i-th input with respect to change in the j-th price, then the elasticity of the i-th input's productivity (ε_{ij}) is given by $\varepsilon_{ij} = -\eta_{ij}$.[3] This is also true for the own price elasticity of demand for the i-th input.

6.A.3 Total Factor Productivity (TFP)

The measure of (TFP) most commonly used is the proportional rate of growth of total factor productivity measure. This value both signifies and quantifies productivity gains or losses. The proportional rate of growth of total factor productivity (TFP) can formally be derived from total factor productivity in the following manner:

$$TFP = Q/F, \qquad (3)$$

where

Q=output

$F = \prod_{i=0}^{n} X_i^{S_i}$

F=aggregate input

X_i=quantity of the i-th input

S_i=the i-th cost share, obtained by dividing i-th input cost by total cost of production.

Taking the natural log,

$$\log(TFP) = \log(Q) - \log(F),$$

$$\log(F) = \sum_i S_i \log(X_i)$$

$$\log(TFP) = \log(Q) - \sum_i S_i \log(X_i) \qquad (4)$$

Totally differentiating (4) with respect to time t,

$$\frac{d\log(TFP)}{dt} = (1/TFP)\ \partial(TFP)/\partial t$$

$$= 1/Q\frac{\partial Q}{\partial t} - \sum_i S_i \frac{1}{x_i}\frac{\partial x_i}{\partial t}$$

$$\dot{TFP} = \dot{Q} - \dot{F} \qquad (5)$$

where a dot over a variable indicates the proportional rate of growth.

Thus, the proportional rate of growth of total factor productivity ($\dot{TFP}$) is simply the difference between the proportional rate of growth of output ($\dot{Q}$), and the share weighted proportional rate of growth of aggregate input ($\dot{F}$). Equation (5) is the conventionally measured Divisia index of TFP.[4]

It is often felt that the productivity measure of equation (5) is really

> "--- a measure of our ignorance, an indicator that tells us how far we are from the ideal,"

(Star, 1974, p. 2).[5] It is a residual measure and tells us nothing of the sources of increases in productivity nor does it indicate possible means of improving efficiency (e.g. increased capacity size, increased capacity utilization, economies of scale, economies of scope, substitution effects, technological effects, etc.). It is simply a difference between Q and F and is only an indexing approach (Diewert, 1979).

6.B Productivity Measurement in This Study

In this section we discuss the measurement of the total factor productivity growth rate or the proportional rate of growth of total factor productivity (equation 5) and relate this equation to the translog method of Diewert (1976), May and Denny (1979) and as also discussed by Fuss (1977).

Diewert (1976) has shown that the Tornqvist-Theil discrete approximation to the Divisia index aggregator is ideal for the linear homogeneous translog function. The rate of growth of productivity as measured by the discrete Divisia index is

$$\log Pv_t - \log Pv_{t-1} = \log(Q_t) - \log(Q_{t-1}) - (\log F_t - \log F_{t-1}) \qquad (6)$$

where

Pv_t=the productivity in year t

Q_t=output in year t

F_t=a measure of aggregate input and is given by

$$\log F_t - \log F_{t-1} = \sum_i W_{it}(\log X_{it} - \log X_{it-1}) \qquad (7)$$

where $W_{it}=(S_{it}+S_{it-1})/2$, an arithmetic average weight of the i-th input cost share to total receipts at time t and t-1, and X_i is the i-th input quantity.

Both the discrete Divisia index and the Fisher ideal index are superlative (ideal) for the linear homogeneous translog function.[6] Thus either of these indices could be used to measure the rate of growth of total factor productivity. However, for computational convenience, the Divisia index is preferred to the other indices for

productivity analysis.[7]

6.B.2 Estimation of the Annual Rate of Productivity Growth

In the productivity analysis we are interested in investigating the annual rate of productivity growth. These results are often summarized in the average annual rate of productivity growth; that is, an average of the annual rates. The annual growth rates (r_g) can be calculated by the residual method as

$$r_g=((Q_t-Q_{t-1})/Q_{t-1})-((F_t-F_{t-1})/F_{t-1}) \qquad (8)$$

Values can be obtained for each of t-1 consecutive years and averaged. Denny and May (1979) have shown (8) to be the discrete approximation to the continuous Divisia index and the translog production function.

The annual rate of productivity growth can also be calculated by using the method of least squares. According to this method the TFP index ($Pv_t=Q_t/F_t$) can be considered as a function of the time variable T such that

$$Pv_t=(1+g)^T \text{ where } T=t-1,\ t=1,\ 2,\ \text{---}\ n. \qquad (9)$$

and g=is the annual rate of growth of Pv_t. Taking the logarithm of both sides of (9), gives

$$\log Pv_t=(t-1)\log(1+g) \qquad (10)$$

The stochastic specification of (10) can be written as

$$\log Pv_t=(t-1)\beta+u \qquad (11)$$

where $\beta=\log(1+g)$, and u =disturbance term. Thus if $\log Pv_t$ is regressed on (t-1), the estimate of the coefficient β can be obtained and g is given by

$$g = \exp(\hat{\beta}) - 1 \qquad (12)$$

which gives the annual rate of productivity growth.[8]

The least squares method implicitly assumes that Pv_t is growing at approximately a constant annual rate of g over the given period of time. This is a strong assumption and does not always hold even approximately. For this study we will apply both the residual method and the least squares method.

6.C Productivity Results

In the productivity analysis our main objective is to determine the rates of total factor productivity growth and to investigate its pattern across two-digit industries. We are also interested in the pattern of input requirement per unit of output over time within each industry. For our purposes we have (1) plotted the TFP ratio index (i.e. $Pv_t = Q_t/F_t$) for all industries; (2) calculated the TFP annual growth rates by the residual method and determined the average annual growth rate; (3) estimated the annual average TFP growth rate by applying the exponential growth rate method and compared them with those of the residual method; (4) compared residual average growth rates with the recent productivity study by Denny et al. (1981). Finally, we have analyzed the pattern of input requirement per unit of output over the period of 1961-1976. In the analysis we have highlighted the significance of resource intensity and productivity growth rates.

6.C.1 Plots of TFP Indexes

The total factor productivity indexes are presented in Table 6.1 and their plots are shown in Figure 6.1. By looking at the plots it can be seen that there is an upward trend over the period across industries with the exception of the miscellaneous category. The pattern of this upward trend is by no means uniform across industries. However, somewhat similar trends appear for food, furniture, primary and chemicals industries and the total manufacturing sector. In most cases TFP increases almost continuously over the period 1961-72 or 1961-73 at which time some disruption appears. About 1973 there is some readjustment after which productivity follows a somewhat different path, often decreasing. Thus on the basis of the plots one can approximately denote two different periods of productivity change 1961-72, 1973-76.

Table 6.1

Trends in Total Factor Productivity in Canadian Manufacturing Industries (1961 - 76)

	Food	Tobacco	Rubber	Leather	Textile	Knitting
1961	.89214	.87511	.48052	.74309	.62759	.53283
1962	.91585	.84624	.55502	.76523	.67923	.54169
1963	.88808	.90379	.56991	.80778	.71776	.57210
1964	.90227	.84682	.59361	.85356	.74438	.62034
1965	.93340	.94501	.62082	.85229	.74014	.66057
1966	.94258	.98585	.63308	.84707	.74300	.72184
1967	.95406	.95918	.63836	.87500	.76974	.72532
1968	.96216	.89717	.59494	.91369	.85781	.82425
1969	.98127	.96234	.60238	.92600	.95627	.85865
1970	.98292	.93530	.95829	.95575	.91951	.88951
1971	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.02253	1.06202	1.04987	1.04238	1.11321	1.08484
1973	1.03357	1.07807	1.09446	1.00856	1.15254	1.11559
1974	.97811	1.08749	1.06954	1.02486	1.11605	1.08343
1975	.96606	1.08871	1.00041	1.03221	1.09620	1.17039
1976	.97552	1.10734	1.07767	1.09970	1.13830	1.23189

	Clothing	Wood	Furniture	Paper	Printings	Primary
1961	.72364	.88404	.77307	.97784	.68089	.89152
1962	.75730	.91198	.76961	.98016	.73091	.90780
1963	.78000	.93658	.79475	.99288	.74657	.91661
1964	.80269	.96242	.81044	1.00886	.78826	.92296
1965	.82871	.97617	.85369	1.00029	.83720	*
1966	.88164	.98293	.89631	.99825	.87423	.92733
1967	.88430	.98869	.91039	.94964	.89444	.89806
1968	.92248	1.01097	.93635	.95339	.90445	*
1969	.93843	.99285	.98269	1.00135	.93002	.92717
1970	.93918	.99038	.96910	.99739	.93776	.93914
1971	1.00000	1.00000	1.00000	1.00000	1.00000	.96286
1972	1.06926	.989065	1.07140	1.03212	1.07276	.97808
1973	1.10638	.99482	1.10604	1.11528	1.00635	1.00000
1974	1.06586	.98229	1.00130	1.19117	.98917	.97998
1975	1.08762	.99395	.98075	1.03574	.09456	.96887
1976	1.13961	1.05743	1.00977	1.07025	1.18497	.97427

* Excluded Observation

TABLE 6.1 Cont'd

	Met. Fab	Mach.	Trans.	Elec. Prod.	Non-Metal	Petro.
1961	.81563	.82255	.58015	.71355	.78986	.93145
1962	.85125	.86205	.63068	.75770	.86136	.97463
1963	.85856	.86403	.68496	.79253	.86569	1.01820
1964	.90443	.93136	.69629	.81695	.89842	1.03373
1965	.93702	.96191	.69304	.84328	.91602	1.04568
1966	.95370	1.00410	.77363	.86194	.92413	1.04595
1967	.95372	.98842	.86443	.87144	.86788	1.04025
1968	.97120	.99631	.91426	.92600	.90508	1.04450
1969	.98469	1.04382	.96472	.96665	.92110	1.02989
1970	.97553	1.07296	.86748	.98563	.90211	1.00703
1971	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.01696	1.00381	1.05417	1.07410	1.04523	1.00257
1973	1.07093	1.02808	1.13260	1.13867	1.08461	1.06993
1974	1.14751	1.10735	1.25377	1.12477	1.08708	1.60117
1975	1.06914	1.02381	1.20585	1.10825	1.05731	1.62319
1976	1.06992	1.00208	1.25670	1.15589	1.05208	1.57280

	Chem.	Misc.	Total
1961	.76467	.89264	.83207
1962	.81061	.91083	.86262
1963	.83492	.90561	.87323
1964	.88780	.95362	.89610
1965	.89619	.98324	.92297
1966	.93351	1.02892	.93147
1967	.91599	1.04430	.93260
1968	.92261	1.13269	.95656
1969	.95734	1.17926	.97739
1970	.95782	.95594	.96867
1971	1.00000	1.00000	1.00000
1972	1.05831	1.05394	1.03287
1973	1.14127	.95316	1.09114
1974	1.10866	.84060	1.12579
1975	.98494	.82029	1.08559
1976	.95514	.87408	1.08890

FIGURE 6.1 PRODUCTIVITY TRENDS

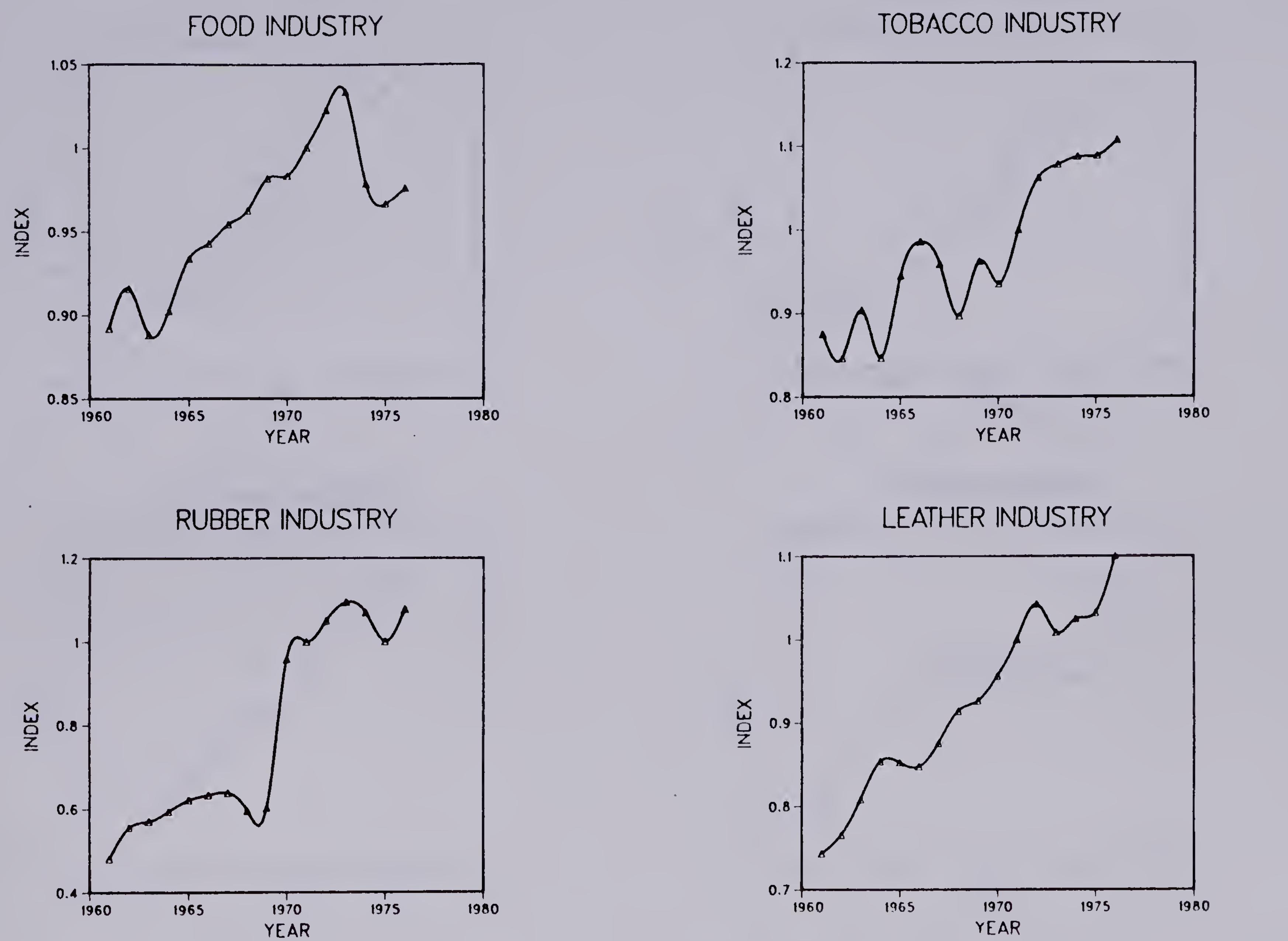


FIGURE 6.1 PRODUCTIVITY TRENDS

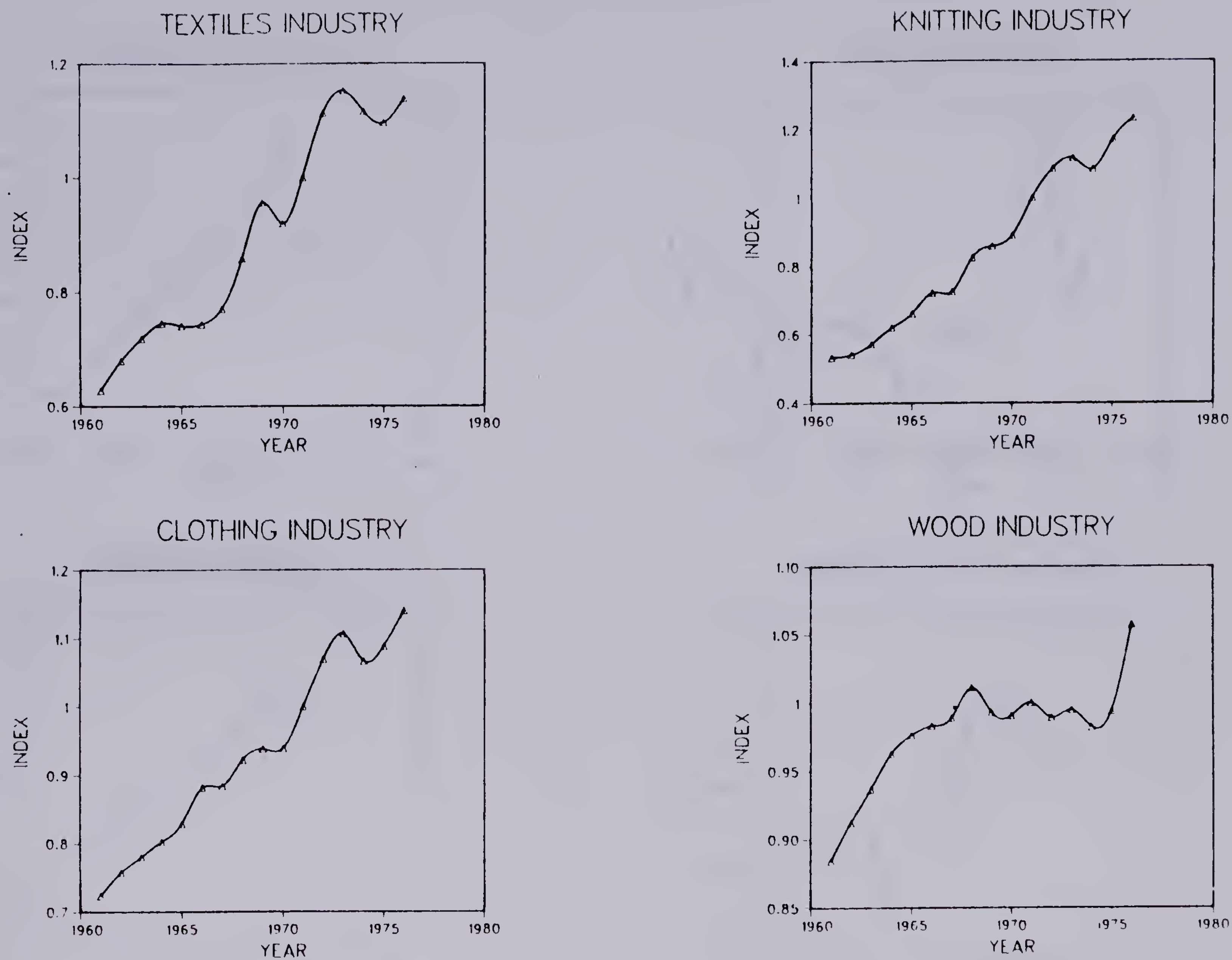


FIGURE 6.1 PRODUCTIVITY TRENDS

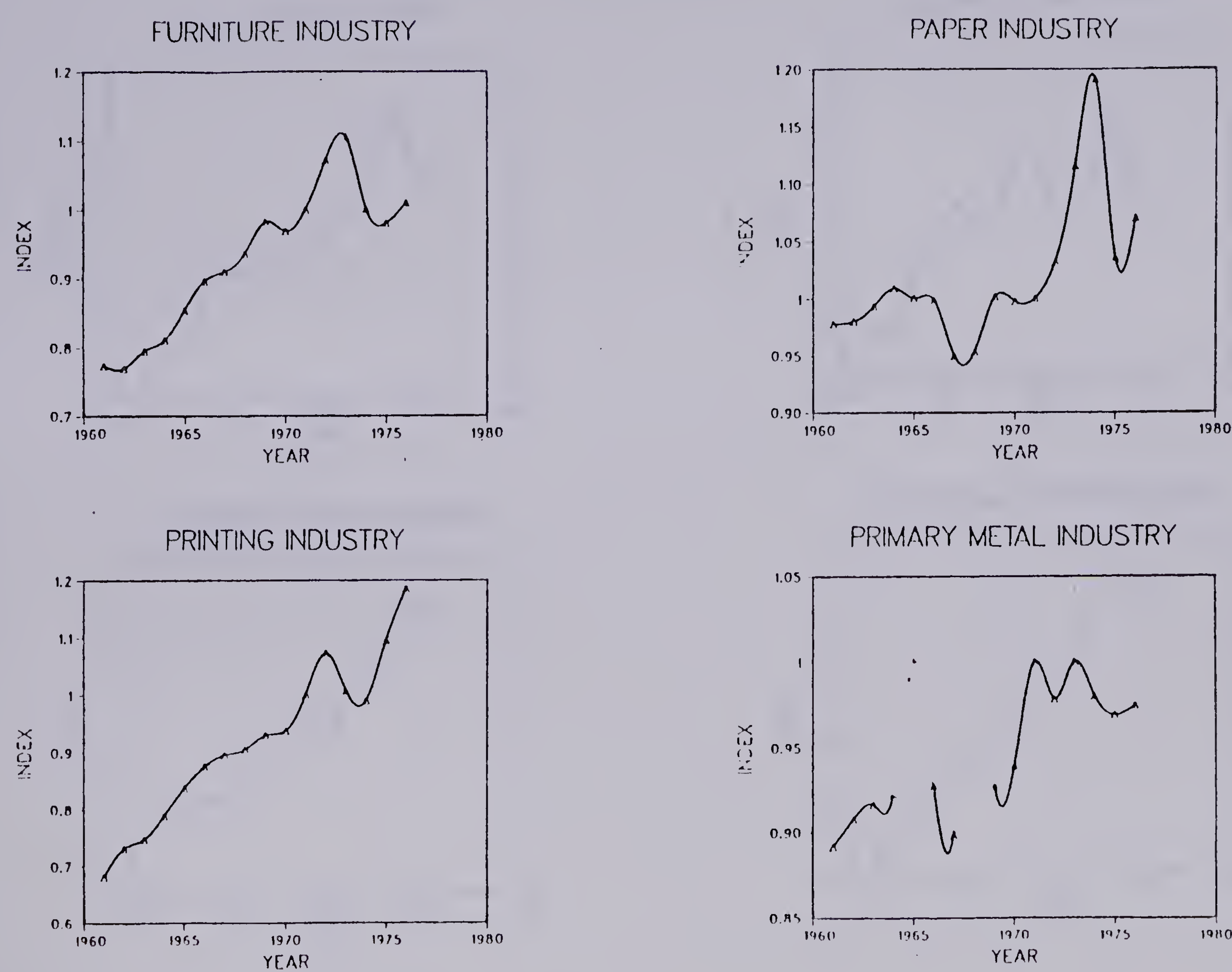


FIGURE 6.1 PRODUCTIVITY TRENDS

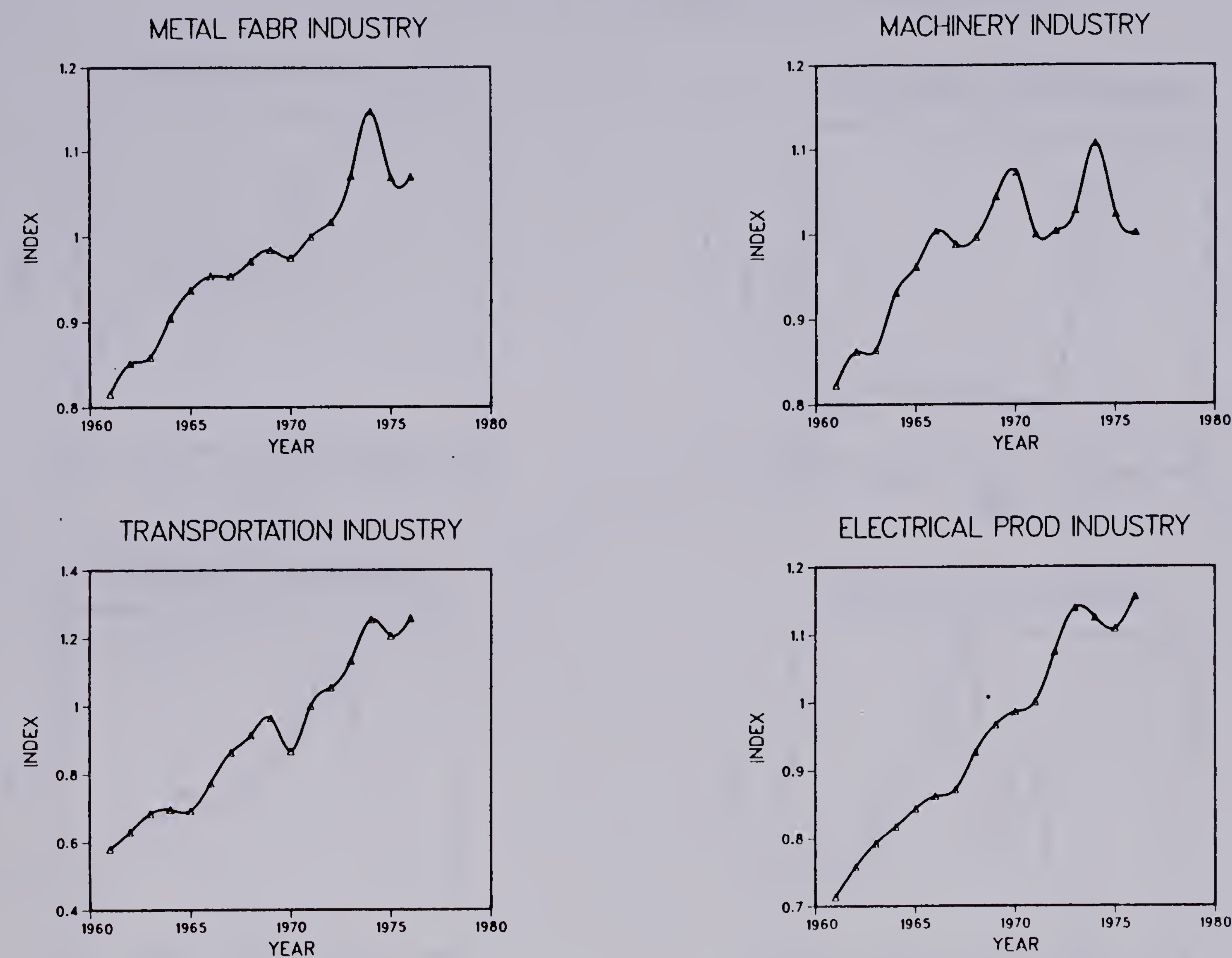


FIGURE 6.1 PRODUCTIVITY TRENDS

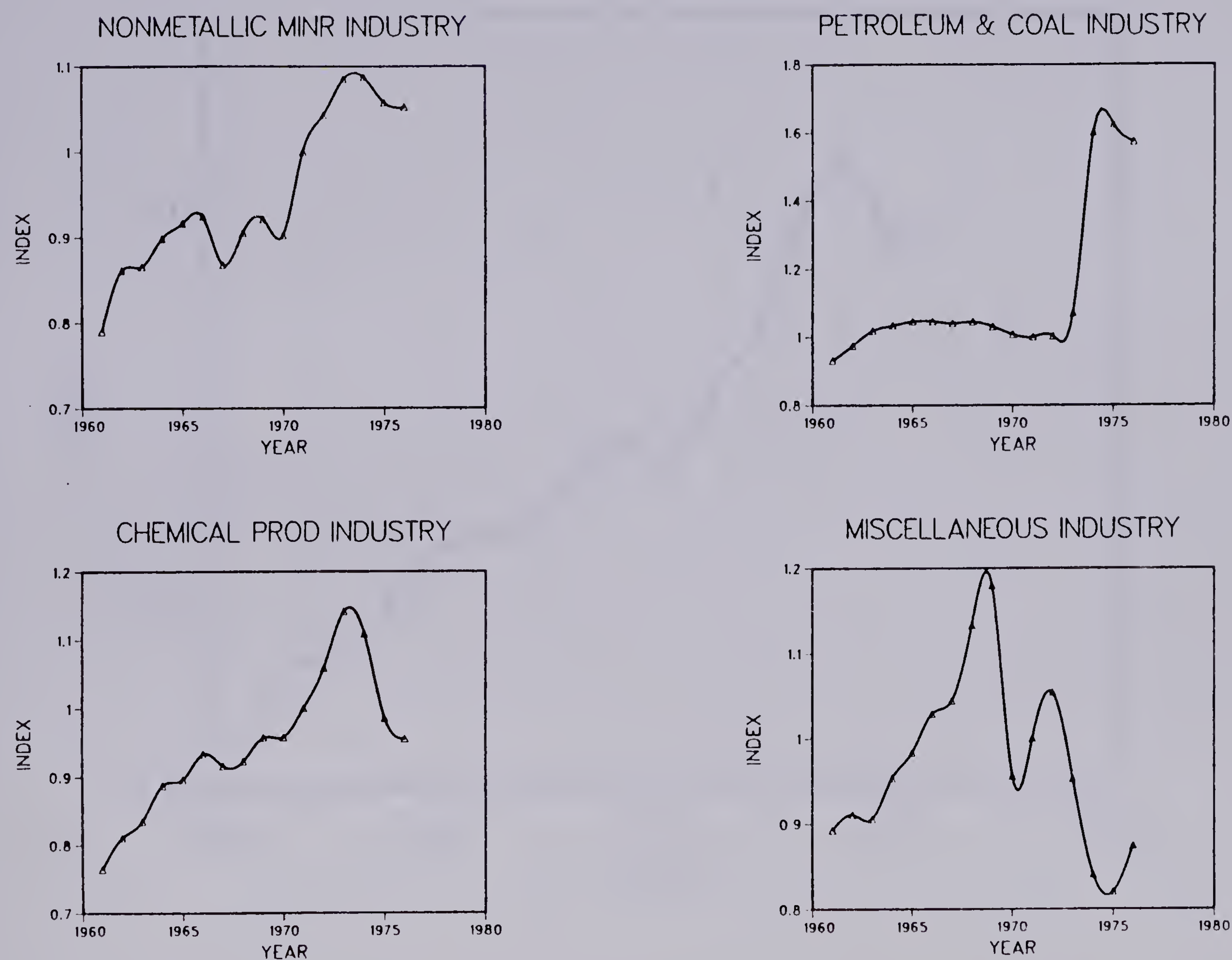
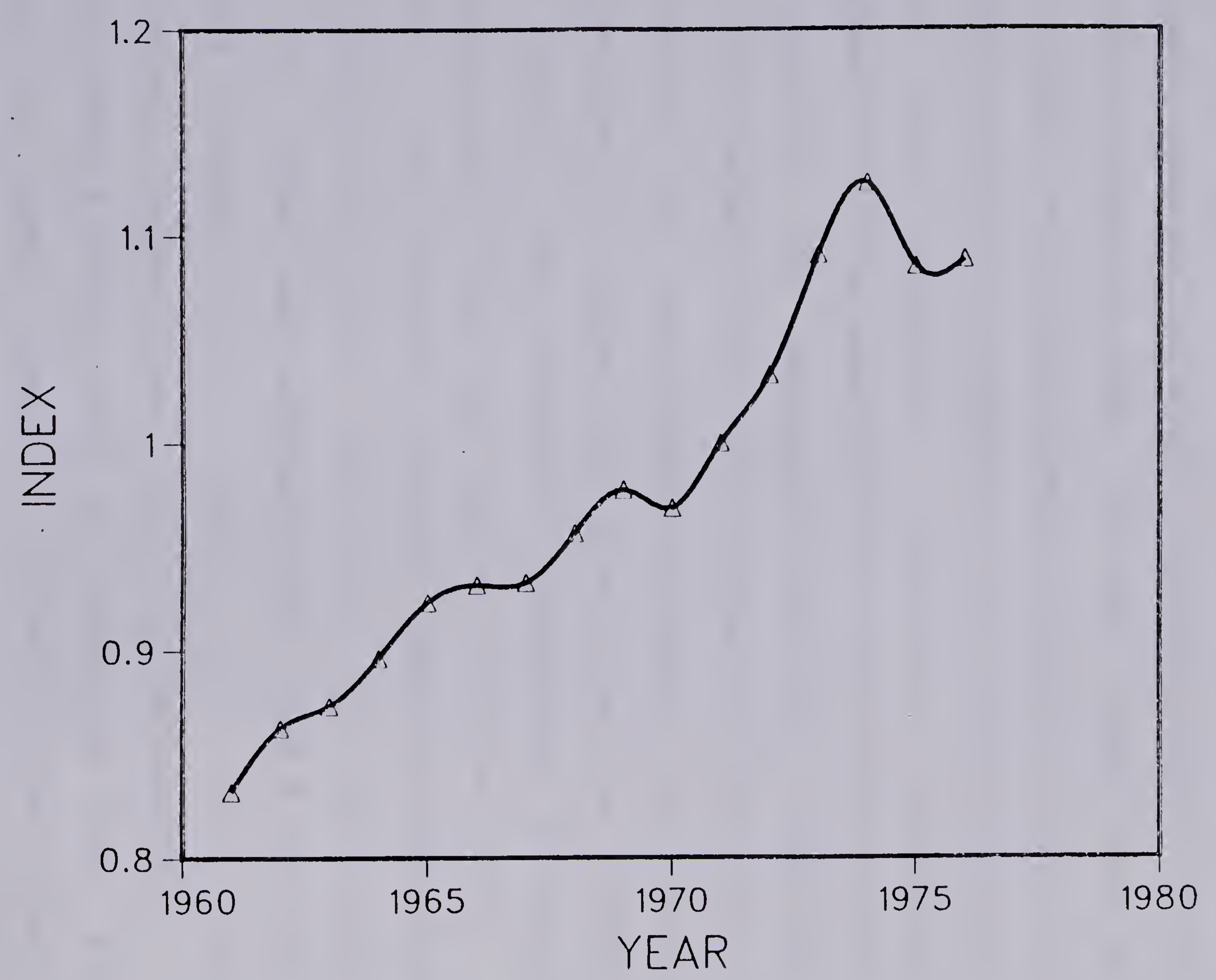


FIGURE 6.1

TOTAL MANUFACTURING INDUSTRY



6.C.2 Rates of TFP Growth

Average annual rates of TFP changes using both the uniform exponential growth rate approach and the residual approach are shown in Table 6.2 and ranked in Table 6.3. Columns 1 and 2 of Table 6.2 show the differences between least squares (exponential growth) estimates and the average annual rate of change of TFP. In most cases these are close. However, in the miscellaneous industry category, the least squares estimate is negative, while the average annual rate of change estimate is positive. Considerable differences can also be observed in the cases of the rubber, wood, printing and petroleum industries. Otherwise, although the trends in total factor productivity are by no means uniform, the least squares estimate of the rates of change are close to those determined from the residual method. Some of the important observations of the TFP growth rates based on the least squares estimates follow.

Most of the resource intensive industries have below average productivity growth rates over the whole sample period; e.g. food and beverages 0.79%, wood 0.71%, paper 0.80% and primary 0.77%, versus 1.91% for total manufacturing. The petroleum industry is the exception.

High (above average) energy use industries other than textiles,(i.e. paper, chemicals, non-metallic and primary) do not have high rates of productivity increase.

A tentative relationship between productivity growth and protection might be suggested by the data. Following

Anastasopoulos and Sims (1981), we may compare productivity growth in protected and unprotected sectors. This comparasion is shown below in Table 6.4 for the same industries that Anastasopoulos and Sims studied in Quebec.

It can be seen in Table 6.4 that generally for the heavily protected industries TFP growth rates are above average (1.91%) suggesting that productivity in these industries may have benefitted by protection. Although "unprotected", transportation, with its high rate of productivity improvement, is affected by the Canadian-United States Auto Pact. Nominal and effective protection rates for the 1961-1970 period are shown for 19 industries in Appendix 4, Table 3. Although exceptions exist (e.g. printing), a similar pattern is observed. However, over the 1961-70 period at least, nominal and effective tariff rates have generally decreased.

TABLE 6.2

RATES OF TOTAL FACTOR PRODUCTIVITY CHANGES

INDUSTRY	1961-76 LEAST-SQUARES ESTIMATE	1961-76 AVERAGE ANNUAL RATE OF CHANGE	1961-72 AVERAGE ANNUAL RATE OF CHANGE	1973-76 AVERAGE ANNUAL RATE OF CHANGE
1. Food	0.79%	0.63%	1.29%	-1.16%
2. Tobacco	1.76%	1.59%	1.77%	1.08%
3. Rubber	5.97%	6.65%	8.69%	1.02%
4. Leather	2.44%	2.60%	3.05%	1.38%
5. Textiles	4.35%	4.25%	5.57%	0.65%
6. Knitting	6.16%	5.88%	6.85%	3.20%
7. Clothing	3.05%	3.13%	3.66%	1.67%
8. Wood	0.71%	1.31%	1.07%	1.95%
9. Furniture	2.21%	1.94%	3.20%	-1.53%
10. Paper	0.80%	0.91%	0.56%	1.90%
11. Printing	3.20%	3.88%	4.31%	2.70%
12. Primary	0.77%	0.61%	0.86%	-0.06%
13. Matal Fab	1.88%	2.06%	2.19%	1.72%
14. Machinery	1.39%	1.68%	2.17%	0.31%
15. Transport	5.33%	5.80%	6.16%	4.79%
16. Electrical Products	3.27%	3.42%	3.96%	1.96%
17. Non-metal.	1.95%	2.13%	2.81%	0.27%
18. Petroleum & Coal Prod.	2.86%	4.33%	0.71%	14.30%
19. Chemicals	1.92%	1.66%	3.11%	-2.34%
20. Misc.	-0.35%	0.22%	1.93%	-4.47%
21. TOTAL	1.91%	1.93%	2.08%	1.51%

TABLE 6.3

ANNUAL GROWTH RATE OF TOTAL FACTOR PRODUCTIVITY (TFP)

INDUSTRIAL GROUPS BY PRODUCTIVITY RANKINGS	EXPONENTIAL TFP GROWTH RATE	INDUSTRY'S PERFORMANCE	AVERAGE ANNUAL RATE OF CHANGE OF TFP
Knitting	6.16	Rubber	6.65
Rubber	5.97	Knitting	5.88
Transport	5.33	Transport	5.80
Textiles	4.35	Petroleum	4.33
		Textiles	4.25
Electrical Products	3.27	Printing	3.88
Printing	3.20	Electrical Products	3.42
Clothing	3.05	Clothing	3.13
Petroleum & Coal Products	2.86	Leather	2.60
Leather	2.44		
Furniture	2.21		
Non-metallic	1.95	Non-metallic	2.13
Chemicals	1.92	Metal Fab.	2.06
Total	1.91	Furniture	1.94
Metal Fab.	1.88	Total	1.93
Tobacco	1.76	Machinery	1.68
Machinery	1.39	Chemicals	1.66
		Tobacco	1.59
Paper	0.80	Wood	1.31
Food	0.79	Paper	0.91
Primary	0.77	Food	0.63
Wood	0.71	Primary	0.61
Miscellaneous	-0.35	Miscellaneous	0.22

TABLE 6.4

TOTAL FACTOR PRODUCTIVITY (TFP) GROWTH RATES IN THE PROTECTED AND UNPROTECTED MANUFACTURING SECTORS

Protected Sectors	Growth Rates (1961-1976)	TFP Unprotected Sectors	TFP Growth Rates (1961-1976)
Tobacco	1.76		
Textiles	4.35		
Leather	2.44		
Knitting	6.16		
		Paper	0.80
		Machinery	1.39
Electrical	3.27		
Clothing	3.05		
Rubber & Plastic	5.97		
Metallic Products	1.88		
		Transport	5.33
Miscellaneous	-0.35		
Furniture	2.21		

Also simple regression analysis using tariff levels and changes to explain rates of factor productivity do not provide evidence of any clear relationship.' Although these results are not revealing, one would expect that unprotected industry should be more efficient (e.g. Boadway and Treddenick, 1978; Saunders, 1980). Using a general equilibrium analysis, Boadway and Treddenick find that removal of tariff protection would result in increases in manufacturing and primary output and decrease in tertiary. Hence, reduced tariffs should, in the long run, improve factor productivity.

Other factors such as market structures, foreign ownership, export share, unit transportation cost (see Saunders, 1980), plant size (see Gorecki, 1976) also effect productivity growth and may be affected by protection policies. Industries developing more plants of the most efficient size will have high productivity growth rates. For example, this seems to be the case for knitting mills and the petroleum industry (see Gorecki 1976, pp. 85-87). However, for the petroleum industry, the sharp rise in the price of non-renewable resource input and its products is the cause of faster TFP growth in the latter years.

6.C.3 Changes in TFP Growth Rates

In most cases, the trend of the TFP index changes considerably around 1972-73. Trends appear somewhat more uniform, however, prior to 1972 (and possibly again after 1972). We have used the residual method to calculate the

average annual rate of change of TFP for the 1961-72 and 1973-76 periods. The results are also shown in Table 6.2. It is interesting to note that there are substantial variations in the growth rates, both within and between industries over different time periods.

It appears that in general productivity growth rates declined after 1973, with the exception of the paper, wood and petroleum industries. Interestingly, these are mostly resource intensive industries which showed low productivity growth rates over the whole 1961-76 period. Cyclical, or in the case of petroleum OPEC stimulated, price movements contributed to this development. We find that the product prices of these industries rose faster in this period than that of total manufacturing.

Productivity growth has declined for the rest of 18 industries. May and Denny (1978) also observed a reduced productivity growth rate for Canadian manufacturing for the 1971-76 period. The decline in productivity trend in the seventies justifies the concern of economists and policy analysts. The question arises what might be the causes of this slowdown in productivity growth.

If we want to explain the changes in productivity trends (i.e. the 1972-76 break), we may consider changes in relative prices which implies that the technology in use is no longer appropriate. Consequently, efficiency is reduced when there is disruption as firms pursue short-run and long-run adjustments to adapt to the new situation. We also

find that the increase in input prices is larger than increase in output prices and therefore, we may expect a decrease in productivity.

There are many possible reasons for the slowdown in productivity. Stuber (1981) in the Bank of Canada Review, lists the following possible reasons:

(1) Cyclically weak demand for output

(2) Relative energy price shocks and higher inflation.

(3) Deceleration of capital-labour ratio

(4) Inter-sectoral movements of labour (e.g. from the agricultural sector to commercial or service sector)

(5) Reduction in research and development expenditures

(6) Changes in labour force characteristics (e.g. more female and youth participation)

(7) Influx of inexperienced or less skilled persons in the work force

(8) A decline in average hours worked

(9) A time lag of adjustment.

Stuber's analysis reveals that items (2) and possibly (3) are the real primary causes of productivity slowdown. However, problems with measurement of capital stock make changes in the capital-labour ratios difficult to determine. The actual causes of TFP slowdown are not yet conclusive. Any future study in this area can investigate this issue more thoroughly.

6.C.4 A Comparison of Annual TFP Growth Rates with the Study by Denny et al. (1981)

The present study is a time series one using Canadian national manufacturing data for the period 1961-76. The study by Denny et al. considers a combined time series cross-sectional analysis of productivity growth rates in Canadian two-digit manufacturing industries in five regions and the rest of Canada over the 1961-75 period.

TABLE 6.5

ANNUAL TOTAL FACTOR PRODUCTIVITY (TFP) GROWTH RATE

RANK	Denny et al (1961-75)	The Present Study (1961-76)
HIGH	Textiles, knitting mills, transportation equipment, chemicals	Rubber, textiles, knitting, transportation equipment, petroleum and coal products
ABOVE	Rubber, machinery, electrical products	Printing, electrical products, clothing, leather
AVERAGE OR BELOW	Food and beverages, leather, furniture, printing, primary metals, metal fabricating, non-metallic minerals, petroleum and coal products	Non-metallic, metal fabricating, furniture tobacco, chemicals, machinery
POOR	Tobacco, clothing, wood, paper, miscellaneous	Wood, paper, food and beverages, primary metals, miscellaneous

NOTE: Underlining indicates industries of same rank in both studies.

HIGH: More than 4%
ABOVE AVERAGE: Less than 4% and more than 2%
AVERAGE OR BELOW: Less than 2% and more than 1%
POOR: Less than 1%

It can be seen in Table 6.5 that there are some differences in the ranking of industries by productivity growth, but in general the rankings are quite consistent . In some cases these differences are minor, but the petroleum and coal products, clothing and chemicals, shift by two positions. Reasons for these differences may include (a) Canadian as opposed to regional data (five regions), (b) different treatment of materials, and (c) the fact that the Denny et al. data does not include 1976.

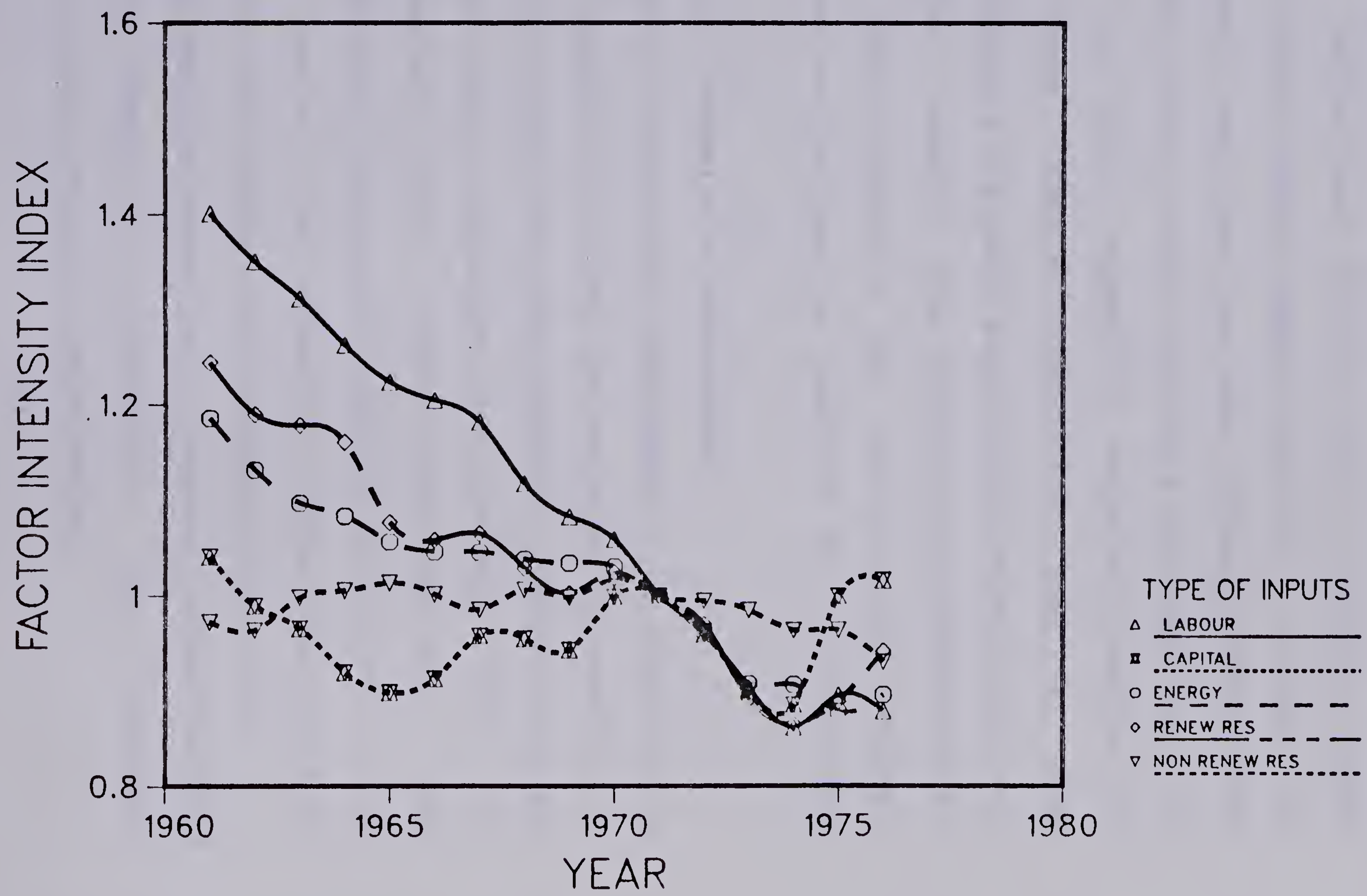
6.C.5 Factor Intensity

The trends in factor intensities over the 1961-76 period are shown in Table 1 of Appendix 4. It can be seen in figure 6.2 below that for the total manufacturing sector the pattern of factor intensities over time differ. Labour, energy and renewable resource input requirements are declining almost until the end of the sample period.[10] The capital input requirement shows a (somewhat flat W-shaped) pattern of substantial fluctuations over time, while the non-renewable resource requirement moves in roughly the opposite way. Substantial variations in the time pattern of input requirements can also be observed for the two-digit industries.

In almost all cases the aggregate input requirement is always declining.[11] However, this declining trend is seen to be relatively slow in the case of resource intensive industries. The decline of the aggregate input requirement implies an increasing trend of total factor productivity

Figure 6.2

FACTOR INTENSITY TRENDS IN MANUFACTURING



ratio. Estimates of elasticity of substitution between labour and capital are positive for all industry classes indicating capital-labour substitutability. Because the price of labour (wage rate) has been increasing faster than capital, labour input has been declining which may also be partly due to factor augmenting technical progress and learning by doing. Similar explanations hold for other input requirements and their substitution relationship with other factors. However, the substitution-complementarity nature of other inputs is not uniform across two-digit industries and so they must be observed on an individual basis.

6.D Parametric Productivity Measurement

Parametric productivity measurement is based on an econometric approach utilizing the estimated parameters of the production and/or the cost function. The values of the estimates are used to decompose the residual (TFP) into various component-effects (scale, technology, etc.). Thus by using additional information about the structure of the production process, the parametric measure can avoid the deficiences of the residual (TFP) measure (Kiss, 1981).

The parametric productivity measure, is derived from the economic theory of production. The production technology of the firm can be described as

$$Q=f(X, t) \qquad (13)$$

where

$X=(X_1, X_2, --- X_n)$

a vector of inputs, and

t=a technical change variable.

The corresponding dual cost function is given by

$$C=G(P, Q, t) \qquad (14)$$

where $P=(p_1, p_2, --- p_n)$, a vector of input prices.

The primal notion of the proportional growth in total factor productivity is defined as the partial derivative of the production function in logarithmic form (holding input quantities constant),

$$\varepsilon_{ft} = \frac{\partial \log f(x,t)}{\partial t} \quad \frac{\partial f}{\partial t} \cdot \frac{t}{f} \qquad (15)$$

which is the percentage change in output due to change in technical progress.

The dual notion of the proportionate change in total factor productivity is defined as

$$\varepsilon_{et} = -\frac{\partial \log G}{\partial t} = -\frac{\partial G}{\partial t} \cdot \frac{1}{G} \qquad (16)$$

where input prices and output quantities are held fixed. This measue is the percentage reduction in total cost due to technical progress (see Berndt, 1978).

The elasticity of cost with respect to output is defined as

$$\varepsilon_{cQ} = \frac{\partial \log C}{\partial \log Q} \qquad (17)$$

The reciprocal of (17) is the return to scale (RS) given by

$$RS = 1/\varepsilon_{cQ} \qquad (18)$$

Ohta (1974) has shown that

$$\varepsilon_{ft} = \varepsilon_{cQ}^{-1}\,\varepsilon_{ct} \qquad (19)$$

In the case of the constant returns to scale $\varepsilon_{cQ}=1$, and $\varepsilon_{ft}=\varepsilon_{ct}$.

According to the non-homothetic translog cost function;

$$\log(C)=\log(\alpha_0)+\sum_i \alpha_i \log(P_i^*)+(1/2)\sum_i\sum_i \beta_{ij}\log(P_i^*)\log(P_j^*)+ \sum d_{iQ}\log(P_t^*)\log(Q)+\alpha_Q\log(Q)+(1/2)\beta_{QQ}(\log(Q))^2. \qquad (20)$$

where $P_i^* = P_i e^{\lambda it}$ $i=1, 2,\ldots,n$. For the translog non-homothetic cost function (20), scale elasticity ε_{cQ} is given by

$$\varepsilon_{ct}=\alpha_Q+ \beta_{QQ}\log(Q)+\sum_i d_{iQ}\log(P_i) \qquad (21).$$

Technical change is given by

$$\varepsilon_{ct}=-\sum_i \lambda_i S_i \qquad (22)$$

Using (21) and (22) ε_{ft} is obtained as

$$\varepsilon_{ft}= \frac{\varepsilon_{ct}}{\varepsilon_{cQ}} =-\frac{\sum_i \lambda_i S_i}{\alpha_Q+\beta_{QQ}\log(Q)+\sum d_{iQ}\log(P_i^*)} \qquad (23)$$

where λ_i denotes the rate of factor diminution.[12] Constant Returns to scale imply that $\alpha_Q+\beta_{QQ}\log(Q)+\sum_i d_{iQ}\log(P_i^*)=1$ and

therefore,

$$\varepsilon_{ft}=\varepsilon_{ct}=\sum_i \lambda_i S_i \qquad (24)$$

(see Gillen and Oum, 1980).[13]

Using the production function (13), the rate of change of output can be expressed as (see May, Fuss and Waverman, 1979),

$$\dot{Q}= \varepsilon_{cQ}^{-1}\dot{F}+\dot{A} \qquad (25)$$

where $\dot{A}= \frac{\partial f}{\partial t}/t$ (26)

and the rate of change of TFP can be derived as

$$T\dot{F}P=\dot{A}+(\varepsilon_{cQ}^{-1}-1)\dot{F}. \qquad (27)$$

That is, TFP=technical change effects+scale effects.

The above relation is obtained by using the residual formula ($\dot{Q}-\dot{F}$). However, since this is now a parametric measure, (using ε_{cQ}^{-1}, an estimated parameter), technical effects and scale effects are separated.

In view of accepting the non-homothetic translog cost function as the appropriate specification for most of the industries including total manufacturing, the parametric measure is the appropriate measure of productivity change.

Other parametric measures are used by Berndt and Khaled (1979), and Caves et al. (1980). In order to obtain a parametric estimate of productivity change we followed the approach of Caves et al. (1980). By this method shifts in the cost function (14) or changes in productivity can be estimated as (holding input constant):

$$\frac{\partial \log G}{\partial t}=\frac{\partial \log G}{\partial \log Q}\,\frac{d\log Q}{dt}-\sum_i S_i\,\frac{\partial \log x_i}{\partial t} \qquad (28)$$

where S_i=i-th input cost share. The discrete approximation

to (28) can be written as

$$-(\log G_t - \log G_{t-1}) = \frac{1}{2}\left\{\left(\frac{\partial \log G}{\partial \log Q}\right)_t + \left(\frac{\partial \log G}{\partial \log Q}\right)_{t-1}\right\}\{\log Q_t - \log Q_{t-1}\}$$

$$- \sum_i \left(\frac{S_{it} + S_{it-1}}{2}\right)\{\log X_{it} - \log X_{it-1}\}$$

$$= \frac{1}{2}\left\{\left(\frac{\partial \log G}{\partial \log Q}\right)_t + \left(\frac{\partial \log G}{\partial \log Q}\right)_{t-1}\right\}\{\log Q_t - \log Q_{t-1}\}$$

$$- (\log F_t - \log F_{t-1})$$

$$(29)$$

where F_t=Divisia index of aggregate input, C=the cost function (20) and factor augmenting technical change is assumed. In terms of the translog cost function, the scale elasticity is given by (21) above. Given estimates of parameters α_Q, β_{QQ}, d_{iQ} (29) can be estimated.[14] It can be seen that (29) does not impose the restriction of constant returns to scale (i.e. $\frac{\partial \log G}{\partial \log Q}$ =1).[15] Also (29) is not derived from the specification that

$C=G(P(p_1, p_2, ---p_n), Q, t)$ (30)

which implies separability of prices ($P=p_1, p_2,---P_n$) from output Q; but instead from the specification

$C=G(P_1, P_2,---P , Q, t)$ (31)

(see Caves et al., 1980).

Factor augmenting technical change will imply that $P_i^*=Pe^{\lambda it}$, where, as before, λi's are the rates of factor price diminuation. Thus with factor augmenting technical change it is less likely that our specification (20) will be affected by collinearity. The equation (29) using the

factor augmenting model (20) provides a total factor productivity measure allowing for non-homotheticity of the cost function. This formulation is used as a measure of productivity in this section and the results are presented in Table 6.6. Column (9) shows the percentage rate of change of productivity growth (TFPN) and column (10) shows the index of total factor productivity (TFPNI).

Total factor productivity growth as measured in section 6.B (and reflected in figures 6.1) is reported in column 8, TFP. This measure is the difference $(\dot{Q}/Q)-(\dot{F}/F)$, that is, column 4 less column 5. We observe that TFP is uniformly greater than TFPN. The reason is that $\frac{\partial \log G}{\partial \log Q}$ is assumed to equal one for TFP, whereas in the non-homohetic case this ratio need not equal one. Returns to scale (column 3) exist but decline throughout the period. Hence the difference. Thus under the accepted non-homothetic model, productivity growth is lower than that implied by the residual total factor productivity measure.

Column (10) shows the index of TFPN which shows an increasing trend with a decline in 1975 and 1976. This trend is consistent with the trend of TFP ratio (figure 6.1 Total Manufacturing Industry).

TABLE 6.6 PARAMETRIC PRODUCTIVITY -- ESTIMATES OF RETURNS TO SCALE, COMPONENT EFFECTS OF TOTAL FACTOR PRODUCTIVITY AND PRODUCTIVITY INDEX

Footnotes

1. Elasticity of cost with respect to output.
2. Proportional rate of change of output.
3. Proportional rate of change of aggregate input.
4. Total factor productivity column 4 less 5.
5. Percentage change in TFPNI.
6. Index of total factor Productivity based on non-homothetic model.

TABLE 6.6 PARAMETRIC PRODUCTIVITY -- ESTIMATES OF RETURNS TO SCALE, COMPONENT EFFECTS OF TOTAL FACTOR PRODUCTIVITY AND PRODUCTIVITY INDEX

YEAR (1)	Ecq[1] (2)	Returns to scale (3)	$\dot{Q}/Q$[2] (4)	$\dot{F}/F$[3] (5)	Technical Change Effects (6)	Scale Effects (7)	(TFP)[4] Total Factor Productivity (8)	TFPN[5] (9)	TFPNI[6] (10)
1961	0.8453	1.18302	0	0	0	0	0	0	0.90523
1962	0.84516	1.18321	0.08031	0.04204	0.03057	0.0077	3.82678	2.43886	0.9273
1963	0.84061	1.18961	0.0565	0.04367	0.00455	0.00828	1.28294	0.35887	0.93063
1964	0.8391	1.19176	0.09557	0.0676	0.015	0.01296	2.79645	1.13015	0.94115
1965	0.84316	1.18601	0.08786	0.05619	0.02121	0.01045	3.16661	1.62952	0.95649
1966	0.8454	1.18287	0.06209	0.0524	-0.00011	0.00958	0.96927	-0.02125	0.95628
1967	0.84487	1.18361	0.02145	0.02021	-0.00248	0.00371	0.12344	-0.20788	0.95429
1968	0.83814	1.19311	0.05038	0.02406	0.02167	0.00465	2.6313	1.77406	0.97122
1969	0.83457	1.19822	0.0539	0.03144	0.01623	0.00623	2.24633	1.30392	0.98389
1970	0.84251	1.18692	-0.00635	0.0026	-0.00943	0.00049	-0.89461	-0.7907	0.97611
1971	0.83747	1.19407	0.04898	0.01612	0.02974	0.00313	3.28649	2.44765	1
1972	0.83761	1.19387	0.07951	0.04515	0.0256	0.00875	3.43525	2.01108	1.02011
1973	0.84071	1.18947	0.10709	0.04797	0.05003	0.00909	5.91217	3.94351	1.06034
1974	0.87458	1.1434	0.06662	0.03379	0.02798	0.00485	3.28285	2.21414	1.08382
1975	0.87413	1.14399	0.06902	-0.03455	-0.0295	-0.00498	-3.4472	-2.7005	1.05455
1976	0.87239	1.14628	0.02294	0.01983	0.00021	0.0029	0.31107	0.01559	1.05471

The methods of Denny , Fuss and Waverman (1979), however, allows the separation of the TFP measure into technical change and scale effects which are shown in column 6 and column 7 respectively.

6.E Summary

1. The analysis of TFP trends reveals a turning point around the early seventies, particularly in 1973/74. In most cases productivity declines after 1973.

2. Average annual rate of change of TFP growth rates vary substantially across industries from about zero to over six percent. Four categories of industry rankings in terms of productivity performance are shown in Table 6.2.

3. Most of the resource intensive industries (food, primary and wood) have a poor rate of growth of TFP.

4. Average annual rate of change estimates are usually different from the exponential growth rates although they are similar.

5. An attempt to relate productivity growth rates with tariff protection does not provide any conclusive evidence.

6. TFP estimates obtained in this study are close to those of Denny et al. (1981).

7. Aggregate input requirements per unit of output declines over time but for some of the resource intensive industries the rate of decline is slower than for most industries.

8. A procedure was devised by which parametric productivity estimates were determined. The parametric estimates are usually smaller than the conventional TFP growth rates. This is because of the presence of scale elasticity effects. In the absence of scale effects, technical change effects and TFP growth rates should be the same.

9. Returns to scale fluctuate over time. The scale measure consistently exceeds one indicating that constant returns to scale is not a valid assumption for the Canadian manufacturing sector.

10. The parametric productivity index is consistent with the total factor productivity ratio index in that parametric productivity estimates also decline in the last two years.

Footnotes to Chapter 6

1. Refer to Kendrick, (1977) p.1

2. For example, studies by Auer (1979), Denny and Fuss (1980), Rao (1979), Denny, Fuss and May (1981).

3. See Berndt (1978).

4. For theoretical discussion see Dhruvarajan et al. (1978), Star and Hall (1976).

5. As quoted by Danielson (1975).

6. See Diewert (1976).

7. The Divisia index is a consistent aggregator and is a discrete approximation to a continuous translog function (see Denny and May, 1979). The Divisia index is easier to compute than either the Fisher ideal index or any other index aggregator.

8. This procedure was used by Danielson (1975) pp. 185-186. For similar trend growth formulas see Postner (1971) pp. 109-112.

9. In order to investigate the effect of tariff protection on productivity change, cross-section regressions of TFP growth both on nominal tariff rates and its rate of change and effective tariff rates and its rate of change were run separately. The results are as follows:

$$\text{TFP(residual)} = \underset{(1.27)}{1.62} + \underset{(1.43)}{0.11}\ \text{Tariff(nominal)} + \underset{(0.12)}{0.30}\ \text{Cntariff}$$

$$R^2=0.382$$

$$\text{TFP(residual)} = \underset{(1.32)}{1.68} + \underset{(-1.11)}{0.06}\ \text{Tariff(effective)} - \underset{(-0.31)}{0.56}\ \text{Cetariff}$$

$R^2=0.29$

where Cntariff is the change in nominal tariff, Cetariff is the change in effective tariff and the t-statistics are shown in brackets.

It follows that the coefficients are not significant. However, we may infer that possibly the higher the tariff protection (nominal or effective) the higher might be the rate of TFP growth rate. This, however, does not seem to support the declining TFP in the latter years.

10. This in turn implies that partial factor productivity (PFPs) are increasing. It is found that the PFP growth rates for L, K, E, R and NR over the 1961-76 period are 3.26, 0.25, 1.95, 1.98 and 0.29 percent respectively. It is also found that like TFP, PFPs also have declined over the 1973-76 period. The rate of growth of PFPs over 1961-72 period are 3.58, 0.8, 2.00, 2.39 and -0.23 percent for L, K, E, R and NR respectively, while for the 1973-76 period these rates are 2.39, -1.27, 1.82, 0.87 and 1.72 percent for L, K, E, R and NR respectively.

11. Aggregate input requirements are shown in Table 2 of Appendix 4. This is the reciprocal of TFP ratio. The declining trend of aggregate input requirement implies rising factor productivity.

12. In a production function (a function of input quantities) the association of λ_i with the i-th input variable X_i such that $X_i^* = X_i e^{\lambda i}$, implies that λ_i is the rate of factor augmentation of the i-th input (X_i). From

the cost function side (a cost function being a function of input prices Pi's and output), $P_i^* = P_i e^{\lambda i}$ which means that P_i is diminished by the dual rate λ_i ($\lambda_i < 0$). This implies that the i-th price variable is declining at the rate of λ_i which has a cost minimising efficiency implication. See Wills (1979).

13. May and Denny (1979) also demonstrated in terms of indexing productivity measures that the rate of growth of productivity arising from the augmentation of any subset of the factors can be calculated from the gross output productivity measure by using the appropriate share to expand the gross output measure.

14. The estimates of α_0, α_Q and β_{QQ} were obtained by using methods which are discussed in Chapter 7, section 7.A.

15. It should be noted that in the non-homothetic total factor productivity case, time is explicitly used as a factor augmenting variable in the cost equation (20) and through the scale elasticity (since in equation 21 scale elasticity $\varepsilon_{cQ} = \frac{\partial \log G}{\partial \log Q}$). On the other hand, in the case of conventional TFP time is only implicitly involved in that one looks at year to year change in outputs and inputs.

Chapter 7. A Simulation of the Impacts of Price Increases

7.A Simulation Method

The impact of price increases (or decreases) of one or more inputs on the pattern of resource use and on the costs of production is very important both to the firm and to the economy. As relative factor prices change, the firm may alter its cost minimizing factor input combination as well as choice of production technology. As firms respond to these price movements, they alter output and employment as they substitute among inputs. Both of these responses have important macro implications for the economy. Being able to simulate this behaviour is, therefore, important for prediction and evaluation of alternative government policy strategies.[1] It may also be noted that as costs change the relative prices of products change so the pattern of demand for manufactured goods also changes. The following sections analyze, theoretically and empirically, the effect of alternative exogenous price changes and policy decisions on target variables, using empirical results obtained in this study.

According to production theory, changes in input prices may have two effects, namely, the substitution effect and output effect. Because we have measured only the compensated factor demand curves we cannot estimate both effects. For example, to determine the output effect we need the Marshallian factor demand functions which requires

[illegible]

knowledge of the elasticity of demand for output which we do not have. Therefore, we analyze only the substitution effect, that is to say the cost minimizing move along the isoquant for a given level of output. As an example, consider the impact of an increase in the price of energy on the optimum cost minimizing mix of labour (L) and other inputs (Q_{OE}), including energy, capital and resources.

Assume that a firm's technology is non-homothetic, marginal products are positive, isoquants are strictly convex and firms minimize cost and face perfectly elastic input supplies. Using figure 7.1 we can illustrate the comparative static results for a change in the price of energy.

Effects of Input Price Changes on Input Demand

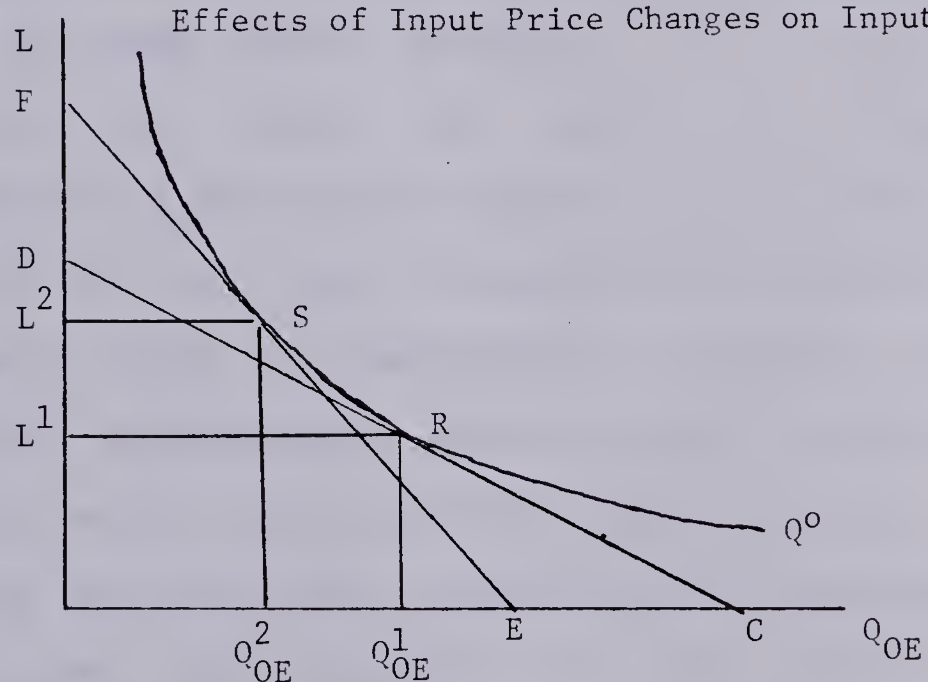


Figure 7.1

If a firm is producing on isoquant Q^o with price of labour P^1_L and the price of other inputs including energy at P^1_{OE}, the isocost line CD is tangent to the isoquant curve at the minimum cost input combination which is point R where output Q^o is produced and Q^1_{OE} units of energy-other inputs

and L^1 units of labour inputs are used. If the price of energy rises causing P_{OE} to rise from P^1_{OE} to P^2_{OE}, this will change the isocost line in order to produce the same level of output. The new isocost line (EF) is now tangent to the same isoquant at the point S where less of Q_{OE} and more of L is used. That is, (L^2-L^1) units of labour input is substituted for $(Q^1_{OE}-Q^2_{OE})$ units of other input mix. This is known as the substitution effect.

In a two input model complementarity is not possible. Therefore, in the above diagram we can only demonstrate the substitution effect. However, in a multi-input model two inputs are often complements. For example, capital and energy are found to complements in the present study and in most of the KLEM model studies. In a multi-dimensional framework it would be easy to demonstrate the complementarity between two inputs, which means that if the price of one of them increases the demand for the other decreases. Using a diagrammatic framework and using a system of subfunctions from a given master production function, Berndt and Wood (1979) have explained the meaning of gross and net substitutability and complementarity.[2] It follows that the existence of net substitutability or complementarity between two inputs depends on whether the gross substitution effect or the expansion elasticity is dominant and this is an empirical issue.[3]

The increase in the price of an input or input components may also have effect on firm's output. For

example, in the above situation one would speculate a negative effect on output. This effect is known as the output effect.

Thus an increase in the price of an input will cause a cost minimizing firm to decrease its use of that input for two reasons; first, the firm substitutes other inputs that are now relatively less expensive. This effect is known as the substitution effect. Second, the increased input price will increase a firm's marginal cost, thereby causing it to decrease output and thus decrease the use of all other inputs. This is the output effect. Similar reasoning can be used to show that a decrease in the price of an input will cause the firm to use more of that input.

Governments may seek to counter the effects of an impact resulting from price increases through tax policies which influence relative input prices. However, tax policies once implemented generally influence more than the target variable and often result in a need to trade off between alternative policy objectives. For example, if a government wanted to reduce the consumption of energy and increase employment, a conflict would result if σLE were negative.

In the context of the Canadian economy, rising energy prices are a very sensitive issue. In Eastern Canada many feel that large increases in energy prices will result in massive unemployment and economic recession. Energy rich provinces argue for energy prices closer to world levels for

the positive effect on provincial revenues and their provincial economies. Resource conservation also argues for higher domestic energy prices. The impact of such moves on the manufacturing sector depends largely on the sign and magnitude of σKE and σLE. Negative values of σKE and σLE would imply reduced capital and employment input. However, σLE has been found positive (that is, denotes substitutability) in most of the factor demand studies including the present study. On the other hand, both positive and negative values have been observed for σKE.

Energy prices are presently increasing in Canada at a steady rate. The recent increasing trend of the prices of renewable and non-renewable resources are also a matter of concern. In this chapter, therefore, we examine the impact of these price increases on the national policy objectives of energy conservation and employment (in the manufacturing sector of the economy). Besides examining the effect of increased energy prices, simulations were also carried out for increases in the price of renewable resources and for increases in non-renewable resource prices.

Simulations were carried out for total manufacturing and a selection of specific two-digit industries. The selection sought variety in factor intensity, technology and regional importance. The set chosen and the provinces in which these are particularly important industries (see Table 3, Appendix 2) follows:

(1) Food and beverages (most of the provinces)

(2) Clothing (Manitoba, Quebec)

(3) Wood (British Columbia)

(4) Furniture (Quebec, Ontario)

(5) Paper (Maritime provinces, B.C. and Quebec)

(6) Petroleum and coal products (Alberta)

(7) Chemicals (Ontario, Quebec)

(8) Total manufacturing (Ontario, Quebec)

7.A.1 Establishing the Cost Function

In order to investigate these effects without imposing the simplifying assumptions used in the above illustration, a flexible model must be specified. The non-homothetic translog model used in the regression analysis is the most appropriate as the test in Chapter 5 has shown. The translog model specified in Chapter 2

$$\log(C)=\log\alpha_0+\alpha_Q \log(Q)+(1/2)\ \beta_{QQ}(\log Q)^2+\sum_i\alpha_i\log(P_i)$$
$$+(1/2)\sum_i\sum_j\beta_{ij}\log(P_i)\log(P_j)+\sum_i d_{iQ}\log(P_i)\log(Q) \qquad (1)$$

assumes instantaneous adjustment of input demand to desired levels.[4] There may be, however, lags in the adjustment process. This might be an important issue but it is not addressed in this thesis. The theoretical framework developed by Kesselman et al. (1977) will be followed in the simulation procedure and instantaneous adjustment will continue to be assumed.

In the five-input (L, K, E, R and NR) non-homothetic translog cost function (model 1), there are 26 unknown parameters to be estimated (after imposing symmetry and

homogeneity restrictions). For the purpose of simulation one requires the predicted value of total cost (C). Since the estimation of share equations does not provide us with all parameters of the cost function, it is necessary to estimate the cost function.

In order to estimate the cost function one may apply either an iterative minimum distance estimator (IMDE) or an iterative Zellner's estimation (IZE) technique as discussed in Chapter 4. It was pointed out there that the application of IMDE sometimes fails to provide estimated coefficients whereas IZE always provides the required coefficients.[5] Therefore, one can apply the IZE technique to estimate the translog model. However, because in our study the number of observations are less than the number of parameters, it is not possible to estimate the non-homothetic cost function (1) that way. Since the general cost function cannot be estimated directly there are two alternative procedures which can be followed:

(a) Estimate a unit cost function which is a function of input prices only.[6] That is,

$$\log(C/Q) = \log\alpha_0 + \sum_i \alpha_i \log(P_i) + \frac{1}{2}\sum_{ij}\sum \beta_{ij}\log(P_i)\log(P_j) \tag{2}$$

(b) Estimate the general cost function; but use the following procedure:

(i) Estimate α_i, β_{ij} and d_{iQ} of the non-homothetic cost function using the system of cost share equations. That is, estimate

$S = f(\log(P_i),\ \log(P_i)\log(P_j),\ \log Q)$

$i = L, K, E, R, NR \qquad j = L, K, E, R, NR \qquad (3)$

(ii) Using the efficient estimates obtained from the estimation of the share equations, calculate that part of the cost function which involve these parameters, namely,

$$\sum_i \alpha_i \log(P_i) + \frac{1}{2}\sum_{ij}\sum \beta_{ij}\log(P_i)\log(P_j) + \sum_i d_{iQ}\log(P_i)\log Q \qquad (4)$$

and denote (4) by PTC (a part of the translog cost function). In order to obtain the remaining unknown parameters α_0, α_Q, β_{QQ}, regress (logC-PTC) on logQ and $(\log Q)^2$. That is,

$$(\log(C)-PTC) = f(\log Q,\ (\log Q)^2) \qquad (5)$$

(iii) Using the estimated parameters in (5) obtain the estimated value of total cost as

$$C = \exp(\log\alpha_0 + \alpha_Q \log Q + \beta_Q (\log Q)^2 + PTC) \qquad (6)$$

Recall that the results of the tests of homogeneity, in Table 5.8 of Chapter 5, show that in all cases except leather, furniture and chemicals, the homotheticity of the cost function is rejected. This implies that only in these cases is the unit cost function a valid specification. In all other cases the non-homothetic cost function is appropriate.

The second procedure outlined above is similar to an extraneous estimation procedure (used in pooling time series and cross-section data). In addition, because this procedure enables one to estimate the general model and so the scale elasticity, it also affords the avenue for

determining parametric estimates of total factor productivity as outlined in Chapter 6, though not all parameters are estimated simultaneously.[7] This second procedure will be followed to simulate the cases in which the technology is non-homothetic.

7.A.2 The Simulation Procedure

Simulation gives more precise estimates of input demands due to changes in input prices than the elasticity estimates. The procedure can be stated as follows. Given the estimated values of the parameters of the translog cost function, in step 1, estimate the stochastic variables (total cost C, cost shares S_i, i=L, K, E, R, NR) for given input prices and for a given level of output (output effect held constant) and obtain the values of inputs which are the base values. In step 2, change the input price of an input (or prices of more than one input), re-estimate the stochastic variables with the same set of parameters and obtain the (shocked) values of input quantities. Finally, take the difference between these values of inputs and the base values obtained in step 1 and calculate percentage changes.

It may be noted that elasticity estimates are based on the first step estimates of S_i only and in this particular application (the translog case) the estimated value of total cost variable (C) is not required, while the simulation requires an estimate of (C) which involves another step.

7.A.2.1 The Case of the Unit Cost Function

(1) Using the estimated values of the parameters, obtain the predicted value of the unit cost, for given values of Q and input prices (P_i). That is, c=C/Q, where c is obtained as an exponential of (2) above.

(2) Estimate share (S_i) as

$$S_i=\alpha_i+\sum_i\beta_{ij}\log(P_j)$$

(3)Given $S_i=P_iX_i/C$, the i-th input quantity X_i is obtained as

$$X_i=(\hat{S}_i x \hat{c} \, x Q)/P_i$$

Therefore, given changes (shocks) in P , the impact on X can be calculated.

7.A.2.2 The Case of the Non-homothetic Translog Cost Function

In this case the total cost C can be directly predicted as $\hat{C}$ and can be obtained as an exponential of (1) above. The remaining steps are the same as above for the unit cost function.

7.A.3 Econometric Problems in Simulation

Problems concerning estimation of the total cost function have been outlined in the previous section. The following additional estimation problems were encountered and are due either to (a) extreme multicollinearity or (b) a negative sign on the coefficient of $(\log Q)^2/2$, the coefficient of which should be positive to give the cost function the appropriate curvature.

If (logC-PTC) is regressed on the explanatory variable $(\log Q)^2/2$, the resultant coefficient is positive. However, if (logC-PTC) is regressed on both of the explanatory variables (that is, logQ and $(\log Q)^2/2$), the coefficient of $(\log Q)^2/2$ becomes negative. In order to examine whether this is due to collinearity we looked at (i) the overall effect on R^2 of adding logQ, (ii) the simple correlation between logQ and $(\log Q)^2$, and (iii) the size of standard errors on logQ and $(\log Q)^2$. We concluded that the problem is collinearity and not a problem of the coefficient of $(\log Q)^2/2$ having a negative sign.

In order to resolve the problem of collinearity two methods were used.

(a) **Ridge Regression Method**

For the linear model

$$Y=X\beta+e$$

the Ridge estimator is given by

$$\hat{\beta}=(X'X+kI)^{-1}X'Y,$$

where k is an optimal scalar which allows the $(X'X+kI)$ matrix to be inverted. The determination of an optimal k is always a problem in Ridge regession. An optimal k may be found using either a search procedure or by minimizing the mean square error (MSE). The minimized MSE Ridge regression method as developed and empirically implemented by Dempster et al. (1977), is followed in this study.[8]

(b) **Mixed Estimation Method**

The multicollinearity impasse can be circumvented by the introduction of additional information. Mixed estimation requires *a priori* information about one or more of the parameters and their variances and in our study the restriction that the coefficient of $(\log Q)^2/2$ must be positive is an *a priori* consideration.

In our model

$$Y = X\beta + e_1 \qquad (7)$$

where we assume $E(e_1)=0$, $Var(e_1) = \Sigma_1 = \sigma_1^2 I_n$, where σ_1^2 is a scalar

and $c = R\beta + e_2 \qquad (8)$

where we assume $E(e_2)=0$, $Var(e_2) = \Sigma_2$

and where R is a matrix of rank r of known constants, c is an r-vector of specified values, e_1 and e_2 are random disturbance vectors.

The model (7) is augmented by the relation (8) and the system is written as

$$\begin{pmatrix} Y \\ c \end{pmatrix} = \begin{pmatrix} X \\ R \end{pmatrix} \beta + \begin{pmatrix} e_1 \\ e_2 \end{pmatrix} \qquad (9)$$

where

$$Var \begin{pmatrix} e_1 \\ e_2 \end{pmatrix} = \begin{pmatrix} \Sigma_1 & 0 \\ 0 & \Sigma_2 \end{pmatrix} = \Sigma \qquad (10)$$

For known Σ_1 and Σ_2, generalized least squares applied to (9) yields an unbiased mixed estimator.

Following Theil (1971), the mixed estimator can be written as

$$\beta_M = (X'\Sigma_1^{-1}X + X'\Sigma_2^{-1}R)^{-1}(X'\Sigma_1^{-1}Y + R'\Sigma_2^{-1}c) \qquad (11)$$

in actual estimation S_1 is substituted for Σ_1 in the usual

form s^2I , Σ_2 is required to be known *a priori*.

Mixed estimation, which usually uses stochastic relationships such as (8) above, is more flexible than the Ridge estimator in that it provides a compromise between the rigors of the full Bayes and the somewhat inflexible Ridge estimator. It also allows *a priori* information to be introduced more naturally and with much greater flexibility than the Ridge and with less computational effort.[9]

To apply mixed estimation prior restrictions are required; in the present case on α_0, α_Q, β_{QQ}. Here the β_{QQ} parameter is restricted to be known and its disturbance term is assumed to be independent and normal. The assumption of normality of the disturbance term allows one to determine the variance of the distribution if one imposes the prior retriction that the parameter lies within a given range with pre-assigned probability (see Belsley et al. 1980). The imposed β_{QQ} coefficient is obtained from a regression of (logC-PTC) on $(\log Q)^2/2$ including the constant term. The estimate of the variance of β_{QQ} obtained from this regression is then used as a known parameter in the stochastic restriction set-up. In this specific application, the standard least squares assumptions are assumed and the estimates are obtained using the simple mixed estimator

$$\hat{\beta}_M = (1/s^2X'X+R'R/\sigma_0^2)^{-1}(1/s_1^2X'Y+R'c/\sigma_0^2) \qquad (12)$$

where $\Sigma_2 = \sigma_0^2$, which is taken as the variance of $(\log Q)^2/2$ as mentioned above and $s^2 = (Y-X\hat{\beta})'(Y-X\hat{\beta})/(n-k)$.

Both Ridge and mixed estimation procedures are used for determining the various non-homothetic total cost functions estimated. OLS procedures are adequate for the homothetic cases.

7.B Simulation Results

Input prices have increased rapidly since the early seventies, especially for energy and resources. For example, for the period 1971-76, increases in the prices of labour, capital, energy, renewable and non-renewable resources are 69, 33, 103, 73 and 117 percent respectively. Relative prices have changed considerably as increases in the energy and resource prices have exceeded those of labour and especially capital. The results presented below are evaluated using as the standard of comparison the mean values of the variables. Since these approximate 1971 prices, the changes occurring by 1976 are similar to changes relative to 1971 prices though labour's price increase from the mean is somewhat larger and resource price increases slightly less than from 1971 prices.[16] In the light of the uneven pattern of input price increases, it is desirable to investigate the impact of significant changes in energy and resource prices on input demand and average cost of production.

The impact of significant input price increases were determined by means of a simulation study carried out using a moderate increase (20 percent) and large increase (50 percent) in the price of energy (case 1), the price of

renewable resources (case 2) , the price of non-renewable resources (case 3). The results based on estimates for a 20 percent increase in the price of E, R and NR are presented in Tables 7.1A, 7.2A and 7.3A respectively, while the results for a 50 percent increase are presented in Tables 7.1B, 7.2B and 7.3B below. The discussion focuses on only one level of each price increase as similar patterns occur for the other.

There are a number of different considerations which one can use in evaluating the results but the important criteria are (a) employment, (b) resource conservation and (c) impact on unit cost of production. Since these are important aspects about which government is presently most concerned (especially with respect to energy), we will focus on these in the discussion. In evaluating the results we have to remember that any given policy will effect all industries. No policy can be made industry specific. Therefore, policy choices must not only reflect tradeoffs within an industry but also tradeoffs between industries.

Results based on both the homothetic and non-homothetic translog cost functions are presented and analyzed. The homothetic model is applied to the cases of furniture and chemicals industries, while the non-homothetic model is applied to the other six industries (that is, food and beverages, wood, clothing, paper, petroleum and total manufacturing).

TABLE 7.1A

SIMULATED EFFECTS OF A 20% INCREASE

IN PRICE OF ENERGY: PERCENTAGE AND QUANTITY CHANGES[a]

INDUSTRY	L	K	E	R	NR	Estimates
Total Manufacturing	.44 (59.64)[c]	-.095 (-5.39)[d]	-7.61 (-85.03)[e]	.20 (10.51)[d]	.52 (31.62)[d]	Mixed
Food and Beverages	.25 (5.09)	.38 (3.32)	-3.38 (-3.76)	.16 (5.48)	-10.15 (-9.63)	Ridge
Clothing	.12 (.71)	-.38 (-.12)	-12.57 (-.63)	.49 (.14)	*	Mixed
Wood	.47 (4.05)	.42 (.82)	-11.10 (-4.87)	.30 (2.69)	-9.55 (-1.78)	Mixed
Paper	1.07 (13.90)	.81 (5.75)	2.84 (7.32)	-3.79 (-24.28)	-1.41 (-.73)	Mixed
Petroleum	.51 (1.22)	-.27 (-.69)	-2.20 (-.44)	*	-.01 (.16)	Mixed
Furniture[b]	.16 (.51)	-1.37 (-.48)	-18.46 (-1.29)	.36 (.18)	4.04 (1.26)	OLS
Chemicals[b]	.59 (4.99)	.24 (1.24)	-11.49 (-12.05)	25.62 (5.13)	2.11 (1.83)	OLS

a: Quantity changes appear in bracket
b: Homothetic model
c: Millions of man-hours
d: Millions of dollars
e: BTUs x 10^{12}
*: Not available

TABLE 7.1B

SIMULATED EFFECTS OF AN INCREASE IN PE

(50% INCREASE)

INDUSTRY	L	K	E	R	NR	Estimates
Total	1.07	-.13	-17.00	.53	1.26	
Manufacturing	(145.38)	(-7.32)	(-190.10)	(28.11)	(76.09)	Mixed
Food and	.64	.92	-9.53	0.43	-22.61	
Beverages	(12.76)	(8.02)	(-10.60)	(14.61)	(-21.47)	Ridge
Clothing	.28	-.83	-26.02	1.11	*	
	(1.65)	(-.27)	(-1.31)	(.31)		Mixed
Wood	1.08	.96	-23.35	.71	-21.32	
	(9.35)	(1.90)	(-10.23)	(6.32)	(-3.97)	Mixed
Paper	2.86	2.26	2.59	-8.23	-2.80	
	(37.13)	(16.09)	(6.66)	(-52.79)	(-1.45)	Mixed
Petroleum	1.17	-.56	-7.49	*	.02	
	(2.83)	(-1.43)	(-1.50)		(.21)	Mixed
Furniture	.35	-3.08	-36.54	.78	9.01	
	(1.11)	(-1.07)	(-2.56)	(.39)	(2.81)	OLS
Chemicals	1.39	.60	-23.93	58.00	4.83	
	(11.80)	(3.12)	(-25.09)	(11.61)	(4.20)	OLS

Note: For footnotes see Table 7.1A

TABLE 7.2A

SIMULATED EFFECTS OF AN INCREASE IN PR
(20% INCREASE)

INDUSTRY Estimates	L	K	E	R	NR	
Total Manufacturing	1.43 (193.96)	-1.67 (-94.20)	.99 (11.12)	-2.03 (-108.18)	.37 (22.15)	Mixed
Food and Beverages	1.52 (30.42)	-1.78 (-15.47)	4.72 (5.24)	-.28 (-9.65)	-2.06 (-1.96)	Ridge
Clothing	-.29 (-1.74)	2.75 (.90)	3.38 (.17)	1.41 (.40)	*	Mixed
Wood	4.51 (39.03)	2.60 (5.13)	6.01 (2.63)	-4.79 (42.79)	23.54 (4.38)	Mixed
Paper	.55 (7.17)	5.75 (41.00)	-10.42 (-26.83)	-2.21 (-14.18)	-19.62 (-10.15)	Mixed
Furniture	.53 (1.69)	-4.44 (-1.54)	2.64 (.19)	-3.13 (-1.56)	4.22 (1.32)	OLS
Chemicals	-.23 (-1.91)	.36 (1.86)	5.43 (5.70)	-1.75 -0.35	-5.74 -4.99	OLS

Note: For footnotes see Table 7.1A

TABLE 7.2B

SIMULATED EFFECTS OF AN INCREASE IN PR
(50% INCREASE)

INDUSTRY Estimates	L	K	E	R	NR	
Total Manufacturing	3.77 (511.66)	-3.46 (-195.40)	2.75 (30.80)	-5.71 (-303.98)	1.29 (77.86)	Mixed
Food and Beverages	3.15 (62.97)	-5.31 (-46.21)	11.34 (12.60)	-.23 (-7.95)	-6.03 (-5.73)	Ridge
Clothing	-.39 (-2.34)	6.48 (2.12)	7.90 (.40)	-.47 (-.13)	*	Mixed
Wood	10.63 (92.08)	5.90 (11.62)	14.36 (6.30)	-10.11 -(90.24)	57.93 (10.78)	Mixed
Paper	1.73 (22.46)	13.99 (99.83)	-24.18 (-62.24)	-5.75 (-36.85)	-45.89 (-23.74)	Mixed
Furniture	1.55 (4.91)	-9.86 (-3.42)	6.39 (0.45)	-8.27 (-4.12)	10.02 (3.13)	OLS
Chemicals	-0.44 (-3.72)	.86 (4.49)	12.19 (12.79)	-6.64 (-1.33)	12.76 (-11.09)	OLS

Note: For footnotes see Table 7.1A

TABLE 7.3A

SIMULATED EFFECTS OF AN INCREASE IN PNR
(20% INCREASE)

INDUSTRY Estimates	L	K	E	R	NR	
Total Manufacturing	-.12 (-16.05)	1.56 (88.35)	3.35 (37.51)	.64 (34.16)	-1.17 (-70.20)	Mixed
Food and Beverages	.92 (18.30)	.49 (4.31)	-7.94 (8.83)	-.026 (-.91)	-9.25 (-8.78)	Ridge
Wood	-.11 (-.97)	-.59 (-1.16)	-3.59 (-1.57)	.45 (4.01)	.10 (.018)	Mixed
Paper	.64 (8.26)	.38 (2.72)	-.31 (-.80)	-1.57 (-10.05)	.94 (.49)	Mixed
Petroleum	10.49 (25.26)	4.05 (10.45)	-1.53 (-.31)	*	-1.59 (-20.31)	Mixed
Furniture	1.32 (4.17)	1.91 (0.66)	17.13 (1.20)	2.46 (1.23)	-21.44 (-6.70)	OLS
Chemicals	1.67 (14.10)	-1.18 (-6.16)	2.0 (2.10)	-24.81 (-4.97)	-1.92 (-1.67)	OLS

Note: For footnotes see Table 7.1A

TABLE 7.3B

SIMULATED EFFECTS OF AN INCREASE IN PNR
(50% INCREASE)

INDUSTRY Estimates	L	K	E	R	NR	
Total Manufacturing	.17 (23.48)	4.14 (234.20)	8.37 (93.62)	1.97 (104.76)	-3.75 (-225.87)	Mixed
Food and Beverages	2.07 (41.46)	1.13 (9.88)	-17.70 (-19.67)	-.03 (-1.02)	-20.06 (-19.05)	Ridge
Wood	-.21 (-1.79)	-1.27 (-2.49)	-7.96 (-3.49)	1.04 (9.33)	-3.40 (-.63)	Mixed
Paper	1.52 (19.71)	.95 (6.75)	-.60 (-1.55)	-3.41 (-21.86)	-1.77 (-.92)	Mixed
Petroleum	25.13 (60.54)	8.05 (20.74)	-6.79 (-1.36)	*	-3.11 (-39.80)	Mixed
Furniture	2.83 (8.96)	4.17 (1.45)	38.49 (2.70)	5.41 (2.70)	-42.03 (-13.13)	OLS
Chemicals	4.01 (33.93)	-2.43 (-12.73)	4.76 (5.00)	-55.95 (-11.20)	-6.46 (-5.62)	OLS

The latter results are based on mixed and Ridge regression techniques. In the following section we explain the results of the total manufacturing sector and compare them with the Denny et al. (1978) study.

7.C The Total Manufacturing Sector

One purpose of the simulation study is to predict from the model the effects of an increase in price of a specific input on that factor and other inputs while maintaining constant output. In the tables above, the figures presented are the percentage changes in the use of inputs, while the absolute changes are shown in brackets. For convenience we may translate these changes into their respective conventional measures--e.g. man-hours into the change in the number of employed persons, taking eight man-hours to be equal to one job. Similarly, energy can be converted into the barrels of oil equivalent and other input demands (e.g. K, R and NR) into millions of constant dollars. The choice of either Ridge or mixed estimates was based on a comparison of the standard error of the estimates and the appropriate sign of the coefficients.

7.C.1 Case 1, Increase in PE

From Table 7.1B it can be seen that a 50 percent increase in the price of energy is predicted to result in a 17 percent reduction in the consumption of energy (that is, the equivalent of 40 million barrels of oil per year) in the total manufacturing sector. The relative changes in other

inputs are more modest. Since E-L, E-R and E-NR are substitutes, the demand for labour increases by about 1.07 percent (72,675 employees), the demand for renewable and non-renewable resources increases by 0.53 percent and 1.26 percent (that is, more than 28 and 76 millions of 1971 constant dollars) respectively. Since E-K are complements, the demand for capital services declines but only by 0.13 percent (that is, by 7.32 million dollars).

The impacts of a 20 percent increase in the price of energy are shown in Table 7.1A. It can be seen there that other than for capital the effects are approximately two-fifths as large as in the case of a 50 percent increase.

7.C.2 Case 2, Increase in PR

The results of case 2 are presented in Table 7.2A and 7.2B. Because renewable resource prices have increased more slowly than energy or non-renewable resource prices, we focus on the 20 percent increase alternative. Results in Table 7.2A show that a 20 percent increase in the price of renewable resource reduces the demand for those resources by 2.03 percent (108 million dollars). Since R-L, R-E and R-NR are substitutes this leads to an increase in the demand for labour of 1.43 percent (96,980 persons), energy consumption of about 1 percent (2.3 million barrels of oil equivalents) and non-renewable resources of .37 percent (22.15 millions of 1971 constant dollars). Even with a 20 percent increase in PR the impacts are considerable. Again R-K

complementarity induces a 1.67 percent decline in the services of capital.

The impacts of a 50 percent increase in PR are shown in Table 7.2B. It follows that the effects are more than twice those with a 20 percent increase.

7.C.3 Case 3, Increase in PNR

The results of increases in the price of non-renewable resources are shown in Table 7.3A and 7.3B. In the case of a 50 percent increase, there is a 3.75 percent decrease in the use of non-renewable resources. Since NR are substitutes with inputs other than labour,'' case 3B yields a 4.14 percent increase in the services of capital (234.20 million dollars), a 8.37 percent increase in the demand for energy (19.6 million barrels of oil equivalents) and about a 2 percent increase in the use of renewable resource (104.76 million dollars).

The impact of a 20 percent increase in PNR is shown in Table 7.3A. It shows that these effects are less than half of the effects shown in Table 7.3B.

To summarize the effects, increases in the price of energy, renewable and non-renewable resources conserves on these resources. Energy demand is particularly responsive to its own price, so increases in PE are expected to be effective in conserving energy. With respect to employment, increases in PE and PR imply increased employment as labour substitutes for resources especially renewable resources.

Labour demand is relatively insensitive to changes in PNR. Capital is complementary with both E and R. The decrease in the demand for capital is much more responsive, however, to an increase in the PR than an increase in PE for which there is only a very small reduction.

7.C.4 A Comparison of Total Manufacturing Results with Those of the Study by Denny et al. (1978)

A comparison of total manufacturing results of the present study and those of the Denny et al. (1978) for a 50 percent increase in the price of energy is shown in Table 7.4. Both similarities and differences occur. The impacts of a 50 percent increase in PE on energy consumption are fairly close. For other inputs, however, the results differ considerably. The estimated impact of the increase in PE on both L and K from this study are much smaller than those projected by Denny et al. Also, they project almost no effect upon material inputs when the same output level is maintained while this study predicts some increases on both R and NR, particularly the latter.

TABLE 7.4

IMPACT OF 50% INCREASE IN THE PRICE OF ENERGY

ON THE INPUTS

(Percentage Changes)

	Denny, May, Pinto (1978)		Present Study		
	1965	1970	1965	1970	1976
L	4.3	4.6	1.09 (140.61)	1.03 (134.02)	1.18 (166.32)
K	-10.7	-8.8	-0.21 (-0.90)	-0.16 (-8.830)	-0.27 (-19.89)
E	-18.0	-19.6	-17.12 (-165.45)	-16.40 (-185.27)	-18.11 (-223.09)
M	0	0	--	--	--
R	--	--	0.54 (25.03)	0.42 (21.88)	0.57 (34.91)
NR	--	--	1.26 (65.07)	1.19 (72.20)	1.47 (111.45)

Some differences are to be expected, given that the studies are based on different sets of data (e.g. different time periods), different models (in their case generalised Leontief) and different ways of measuring labour and capital inputs. However, these two studies have quite different implications for the impact of energy price increases on other factors, especially L and K. This study indicates much smaller adjustments in those inputs and so has different implications for decision makers. Which of these results is the more reliable requires further study.

Even though the percentage changes for labour and capital found in this study are smaller, in absolute terms these effects are still important and the total effect considerable though more widely dispersed (i.e. through the R and NR sectors). For example, in the above case 1.09 percent increase in the demand for labour means a demand for 70,305 people and a 1.18 percent increase implies about 83,160 more jobs. Similarly for R, a 0.54 percent increase means a demand worth about 25 millions of constant 1971 dollars, and for NR 1.26 percent means an additional demand amounting to 65 millions of 1971 constant dollars.

7.C.5 Impact on the Two-digit Level Industries

The simulation results for specific price increases in selected two-digit industries are shown in the above Tables 7.1-7.3. It can be seen that in almost all cases signs of the own demand due to an increase in own prices are negative. Exceptions are paper, for cases 1A and 1B (Tables

7.1A, 7.1B), clothing for case 2A (Table 7.2A), wood and paper for case 3A (Table 7.3A). In the case of the paper industry Denny et al.(1979) found a positive value of η_{MM} (own elasticity of demand for materials) for their static model. For clothing and wood, it follows that a moderate increase is not effective in an economic sense (increase in demand due to increase in own price). We note that the input shares in these cases are relatively small.

The impacts for total manufacturing masks a variety of effects upon specific industries. If the price of energy (PE) increases by 50 percent the decrease in the quantity demanded varies considerably across industries. Decreases range from -7.8 to -36.5 percent. It can be seen that the effects on the demand for labour is almost always positive and that quite different effects on employment by industry can be observed. For instance, in the case of paper, the effect is about a 3 percent increase in the demand for labour, while almost zero for clothing.

Among these industries capital appears as both a complement and a substitute, the percentage changes varying from -3.05 to 2.26. The non-renewable resource input is also a complement or a substitute depending on the industry. Almost always, with the exception of chemicals, the effects on NR is opposite to that of capital. Unlike capital, NR shows relatively large responses.

Renewable resources are substitutable with energy except in the paper industry. The responses of R is

exceedingly large for the chemicals industry. If the price of renewable resources (PR) increases by 50 percent, own demand for R decreases but the change is not as large as in the case of energy. The effect on employment is substantial with the exception of clothing and chemicals and the percentage changes varying from 1.55 to 10.63 percent in the other industries.

Capital can either a complement or a substitute for R. The changes range from -9.86 to 13.99 percent. Non-renewable resources can also be either substitutes or complements depending on the industry. As before, with the exception of total manufacturing the effects on NR is opposite to that of capital across industries in terms of sign.

Renewable resources and energy are substitutes (with the exception of paper). The increases in the demand for energy as a result of a 50 percent increase in PR vary from 6.39 to 14.36 percent.

If the price of non-renewable resources (NR) increases by 50 percent the own demand for NR decreases substantially (varying from -1.77 to -42.03 percent). The effect on the demand for labour is usually a moderate increase but for wood, which shows a -.21 percent decrease, and petroleum with a 25.13 percent increase. Capital, energy and renewable resources appear as both complements and substitutes and display a wide range of relative changes.

7.C.6 Total Manufacturing and Two-digit Level Industries

In the previous sections we have analyzed the effects of energy or resource price increases on total manufacturing and across two-digit level industries. It follows that a given percentage increase in the price of either energy, renewable or non-renewable resources may result in considerably different impacts on total manufacturing and the specific two-digit level industries. For example, a 50 percent increase in the price of energy may result in energy saving by 10 percent for the food industry, while for the total manufacturing sector the rate of energy saving is a 17 percent reduction. A 50 percent increase in PR causes a decrease in the use of R. In the wood industry the 10.11 percent decline is almost twice as much as in the total manufacturing sector but in the food industry the reduction is very small. Similarly, it can be seen that the effect of PNR increases are also quite different between total manufacturing and the two-digit level industries. Therefore, the effect of an increase in the price of either energy or resources, the impact of which on total manufacturing may be seen as desirable from the point of view of energy saving or higher employment, may have quite different or uneven impacts across the specific two-digit level industries.

7.D.1 The Effect of Energy and Resource Price Increases on Average Cost of Production

The effect of energy and resource price increases on the average cost of output are shown in Table 7.5. It can be seen there that even a large 50 percent increase in the price of energy results in only 1.65 perecent increase in the average cost of output for total manufacturing. On the other hand, a similar increase in the price of R and NR results in more than 8 and 10 percent increase in the average cost of output. Therefore, energy, because it is a small share of the total cost of production, has a much smaller effect on the average cost of output than resources for a given percentage price change.

At the two-digit industry level it can also be seen that the effects of resource price increases are significantly higher than those of energy price increases other than for chemicals. For example, for the food, wood and paper industries a 50 percent increase in PR may result in more than 28, 21 and 10 percent increase in the average cost of output respectively. Similarly, a 50 percent increase in PNR results in more than a 37 percent increase in the average cost of production for the petroleum industry. These are, of course, resource intensive industries.

The chemicals industry, however, is an exceptional case in that the impact of energy price increases are parallel to those of R and NR price increases. This occurs because

TABLE 7.5

THE EFFECT OF RISING RESOURCE PRICES

ON UNIT COST OF PRODUCTION[a]

	TOTAL MANUFACTURING			FOOD		
	Original Unit Cost	Unit Cost After 20% Increase	Unit Cost After 50% Increase	Original Unit Cost	Unit Cost After 20% Increase	Unit Cost After 50% Increase
PE	.94385	.95045 (.70)	.95947 (1.65)	1.00268	1.00626 (.36)	1.01137 (.87)
PR	.94385	.97723 (3.54)	1.02589 (8.69)	1.00268	1.11660 (11.36)	1.28719 (28.37)
PNR	.94385	.98541 (4.40)	1.04627 (10.85)	1.00268	1.00551 (.28)	1.00930 (.66)

	CLOTHING			WOOD		
	Original Unit Cost	Unit Cost After 20% Increase	Unit Cost After 50% Increase	Original Unit Cost	Unit Cost After 20% Increase	Unit Cost After 50% Increase
PE	.85756	.85889 (.16)	.86062 (.36)	1.06238	1.06707 (.44)	1.07323 (1.02)
PR	.85756	.86718 (1.12)	.88159 (2.80)	1.06238	1.15795 (9.0)	1.29382 (21.78)
PNR	*	*	*	1.06238	1.06441 (.19)	1.06737 (.47)

Note: a. percentage changes are shown in brackets.

TABLE 7.5 (continued)

THE EFFECT OF RISING RESOURCE PRICES

ON UNIT COST OF PRODUCTION

	PAPER			PETROLEUM		
	Original Unit Cost	Unit Cost After 20% Increase	Unit Cost After 50% Increase	Original Unit Cost	Unit Cost After 20% Increase	Unit Cost After 50% Increase
PE	1.14973	1.17045 (1.80)	1.20181 (4.53)	1.05870	1.06075 (.19)	1.06373 (.48)
PR	1.14973	1.20050 (4.42)	1.27450 (10.85)	*	*	*
PNR	1.14973	1.15404 (.38)	1.16049 (.94)	1.05870	1.21903 (15.14)	1.45569 (37.50)

	FURNITURE			CHEMICALS		
	Original Unit Cost	Unit Cost After 20% Increase	Unit Cost After 50% Increase	Original Unit Cost	Unit Cost After 20% Increase	Unit Cost After 50% Increase
PE	0.9475	0.9504 (.31)	0.9538 (.66)	0.8688	0.9391 (8.09)	0.9551 (9.93)
PR	0.9475	0.9689 (2.26)	0.9997 (5.51)	0.8688	0.9628 (6.68)	0.9336 (7.46)
PNR	0.9475	0.9595 (1.27)	0.9732 (2.71)	01.8688	0.9387 (8.05)	0.9560 (10.04)

Note: a. percentage changes are shown in brackets.

chemicals is a high energy using industry.

The important thing to be noted here is that while most of the attention with respect to manufacturing adjustment has focused on energy prices, increases in resource prices may really be more important with respect to substitution and increases in the average cost of production during this same period. An investigation of the difference between the 1976 cost of production and the mean cost of production over the 1961-76 period shows that the contribution of renewable and non-renewable resource cost increases are higher than that of energy cost increases. It is found that 36.14 percent of the increase in total cost is attributed to the increase in labour cost, 13.07 percent to capital cost, only 4.28 percent to energy cost, 15.42 percent to renewable resource cost and 31.09 percent to non-renewable resource cost increases. Thus almost one-half of this increase in average cost (and an even larger share of the increase over 1971 costs) is attributable to renewable and non-renewable resource price increases. This fact demonstrates the desirability of treating renewable and non-renewable resources as separate inputs of production.

It is useful to reflect on certain policy measures to control manufacturing costs in view of this analysis of the source of these cost increases. Programs to control energy price increases have been advanced and defended on the grounds that they would enhance the competitiveness of Canadian manufacturing. Over all manufacturing the impact

of such policies will be small. More important are the costs of other inputs, particularly labour and natural resources. The competitiveness of Canadian manufacturing will rely more heavily upon a productive and competitive labour force and natural resource industries.

7.D.2 Regional Implications of Simulation Results

We have mentioned before that simulations were done for total manufacturing and for a few selected industries. Other than cost shares and technology, one of the main criteria of selection of those industries is their regional significance.[12] In the earlier section of this chapter the industries were associated with their predominant region. Now in order to briefly discuss the regional implications of the results, we consider both the input (e.g. E or R or NR) and the regional representation of the industry. For example, chemicals is an energy intensive industry concentrated in Ontario and Quebec. Wood, on the other hand, is a renewable (forestry) resource based mainly in British Columbia. Similarly, petroleum and coal products is a non-renewable resource based industry centered in Albetra.

In order to indicate briefly the regional implications of input price changes as an aspect of interindustry variation we may consider increases in the prices of E, R and NR in turn. Increases in the price of energy has a considerable effect on input demand and average cost of production on most of the industries, particularly on total manufacturing, food and chemicals industries. From the

[illegible]

regional point of view this indicates that this will effect most of the regions, but particularly Ontario and Quebec.

Increases in the prices of renewable resources (PR) will have significant effects on the wood and paper industries and also some effect on the food industry as well. This means that increases in the price of renewable resources will mostly affect the British Columbia and the Maritime provinces. With respect to the food industry, this effect is distributed across most of the provinces.

Increases in the price of non-renewable resources will have a significant effect on the petroleum and coal products industry. This implies that it will have most of its effect in the Province of Alberta. However, some effects on other regions and provinces are also obvious in Tables 7.3A and 7.3B.

Finally, it should be noted that the more significant regional implications of a price increase for a resource may be on the supply side (e.g. regional, particularly, provincial resource ownership) rather than on user or manufacturing side.

7.E Important Findings of the Simulation Study

Some of the important findings which emerge from the simulation study are the following:

(1) Like the study by Denny et al. (1978), increases in the price of energy have significant impacts on the use of energy.

(2) Unlike materials as an input in Denny et al.'s study, both renewable and non-renewable resources in the present study do respond significantly to price changes and hence impact on other inputs.

(3) The total manufacturing industry and two-digit level industries are also differently affected by a given percentage increase in the price of energy or resources.

(4) Increases in the price of energy and resources generally create employment. In the case of capital, however, which occurs as either a substitute or a complement to energy depending on the industry, energy price increases may result in either an increase or reduction in capital intensity.

(5) The effect of energy price increases on average cost of output are usually small and much less than the effects of resource price increases of similar magnitude.

(6) The region specific industries are very differently affected by a given percentage increase in the price of energy or resources.

Footnotes to Chapter 7

1. Simulation provides effects of input price change on input demand in absolute magnitudes as opposed to an elasticity estimate which is in terms of percentage changes. However, both simulation and elasticity estimate should provide similar implications. See the discussion of the simulation procedure in the following section.

2. The net substitution elasticity of factor i with respect to factor j is defined as the sum of the gross substitution elasticity and the expansion elasticity. Expansion elasticity characterizes movement along an expansion path. (See Leif Johansen (1972), pp. 124-26 as referred to by Berndt and Wood (1979)). The expansion elasticity being always negative, net elasticity of substitution may be either positive or negative depending on whether it is dominated by gross substitution elasticity or not. This in turn will determine substitutability or complementarity.

3. See Berndt and Wood (1979) p. 346.

4. The increases in input prices imply changes in relative prices and this in turn implies that firms will make adjustment to such changes through substitution of inputs or changes in output. Although this may happen over time, the adjustment process inherent in the model assumes this to be immediate. Instantaneous adjustment implies a static model, while a dynamic model takes into account the process of adjustment. For recently developed dynamic

adjustment model see Denny et al. (1979), Berndt, Fuss and Waverman (1979) and Berndt, Morrison and Watkins (1979).

5. This might be because IMDE as available in TSP (version 2.4, 1973) runs in single precision and our written IZE program in APL runs in double precision.

6. Unit cost is a function of input prices only. For the derivation of the unit cost function from the total cost function see Chapter 2.

7. Parametric productivity uses the estimates of α_0, α_Q and β_{QQ} which are not available from the estimation of share equations only. Maddala (1971) discusses the conditions under which extraneous estimates are consistent. They will in general not be efficient.

8. The Ridgm is one of the variants of "continuous shrinking" methods. The Ridgm method is motivated by the Bayesian interpretation of Ridge. The method implies that the observable least squares estimators, say a_i, are marginally independently and normally distributed with mean zero and variance $\sigma^2/\lambda_i + \omega^2$ where $w=\sigma^2/k$, k is the unknown scalar to be determined and λ_i is the eigen value. It turns out that for p number of explanatory variables, the prior expectation of $\Sigma a_i^2/(\omega^2+\sigma^2/\lambda_i)$ is p. According to Dempster et al. (1977), Ridgm chooses k to make this expression equal to its prior expectation, when s^2 is substituted for σ^2 and $k=\sigma^2/\omega$, where $s^2=(Y-X\hat{\beta})'(Y-X\hat{\beta})/(n-p)$, where n is the size of the sample. This means that the solution of the relation

$$\Sigma_i \frac{a_i^2}{\sigma^2/k+\sigma^2/\lambda_i} = p$$

or $$\Sigma_i \frac{a_i^2}{\sigma^2/k+\sigma^2/\lambda_i} - p = 0 \qquad (1)$$

gives us optimal value of k. For two explanatory variables (1) implies a polynomial of degree 2. Therefore, in that case, we choose that value of k which is between 0 and 1. For details see Dempster et al. (1977).

9. See Belsley, Kuh, and Welsch (1980).

10. The rate of increases in the prices of L, K, E, R and NR from mean price to 1976 prices are approximately 83, 32, 96, 61 and 95 percent respectively.

11. The effect on labour input is unstable in this case, in that for a 20 percent increase in PNR, the sign of the simulated effect is negative (as expected), while for a 50 percent increase, the effect on labour input is positive. However, the effect is very small. Also we find that σLNR is statistically insignificant at the 5 percent level.

12. In this case regional significance is determined on the basis of the percentage share of value of shipments (as shown in Table 3 of Appendix 2) in ten Provinces and hence of the regions. It is obvious in Table 3, for example, that wood industry is prominent in the British Columbia region.

Chapter 8. Summary and Conclusions

The main objective of this study has been to investigate the role and use of energy, renewable resources and non-renewable resources in the Canadian manufacturing industries using the translog production technology as revealed through the translog cost function. The non-homothetic form of the translog cost function has been the maintained hypothesis on the basis of evidence from previous studies which have demonstrated the appropriateness of the function.

In the introductory chapter it was argued that like energy, renewable and non-renewable resources are inputs of policy significance and that they should be treated separately so the effects of resource price fluctuations can be investigated.

The empirical analysis demonstrated that R and NR are separate factor inputs which have a significant role in firms' production decisions and that they behave somewhat differently from the materials input used in KLEM models, where materials consists of renewable and non-renewable resources and other materials. Other materials were excluded in this study assuming that they are separable (independent) from other inputs. The recent substantial increases in renewable and non-renewable resource prices (e.g. grains, live animals, other agricultural products;

crude mineral oils, etc.) motivated the analysis.

In Chapter 2, the methodology of this research was developed, the general model derived and the general translog cost function mathematically specified. The conditions for testing homotheticity, homothetic separability and other separability hypotheses were developed. Details of the estimation and testing procedures were outlined in Chapter 4.

Data construction was outlined in Chapter 3 and features of the data were discussed in the initial sections of Chapter 5. Price trends were analyzed and it was found that PL (price of labour) and PR (price of renewable resources) have a regular upward movement while PK fluctuates having a somewhat cyclical pattern due to variations in effective tax rates, real rate of return and other factors. The prices of energy (PE) and non-renewable resources (PNR) have sharp rising trends. Input cost shares show considerable variation. It is interesting to note that K and NR shares tend to move in opposing directions over the 1961-76 period, while the movements of other input cost shares are somewhat more uniform.

Homotheticity of the translog cost function was tested and this hypothesis was rejected for most of the industries. Exceptions were the leather, furniture and the chemicals industries. Also homothetic separability and other separability hypotheses were tested. Our conclusion is that Canadian manufacturing industries are mainly characterized

by the non-homothetic structure of the production technology. A similar conclusion was arrived at by Denny et al. (1978). For the Canadian agricultural production technology, Lopez (1980) also derived a similar conclusion.

As to the tests of separability of inputs, it was found that L, K and E are not separable from the resource sector (R and NR). Also R and NR are not separable in a few cases, while E and R and E and NR are not separable in most cases. These results indicate the importance of treating resources as distinct inputs.

The analysis of empirical results in Chapter 5 also provide estimates of the elasticities of demand and elasticities of substitution. Changes in the prices of energy and resources were found to affect industries' production decisions but responses were generally inelastic. There are considerable differences in price elasticities across two-digit industries and also between total manufacturing and the two-digit industries. Therefore, it is necessary to investigate both total manufacturing and two-digit industries when studying the nature of demands for energy and resources in this sector.

It has been found that with the exception of the paper industry, energy and renewable resources are substitutes. Therefore, it may be concluded that firms substitute renewable resources for (relatively expensive) energy resources. However, it is not generally true that renewable resources are substituted for non-renewable resources,

because R and NR have been found to be both substitutes and complements. Energy and non-renewable resources are also found to be either substitutes or complements depending on the industry in question. Thus the utilization of E and NR differ across industries even though both are depletable resources.

Capital-energy complementarity has been found in 15 out of 21 cases indicating that this is not a general result and as such no general conclusion can be made regarding this parameter. Denny et al. (1979) also arrived at somewhat similar conclusion for Ontario manufacturing.

Labour and energy are substitutes in all industries. Therefore, energy price increases will result in an increase in employment.

The substitution parameters σLR, σLNR, σKR, σKNR, σER, σENR receive particular attention in the present study. It is found that these parameter estimates provide greater insight and have different implications than their parallels (σLM, σKM and σEM) in the KLEM models. For example, a comparison between total manufacturing results with the U.S. KLEM model indicates that in general there are both similarities and dissimilarities among these parameters. In the present study, the value of σENR is very close to σEM in the U.S. study, while σER is about one-third of σEM and σENR. Similarly, it is found that for the two-digit level food manufacturing these parameters behave somewhat differently than those of the KLEM models. This clearly

indicates the necessity of separating R and NR from materials both for production specification as well as resource management policy purposes.

Productivity analysis shows that the annual rates of total factor productivity (TFP) growth rates are quite different across industries (Chapter 6). This may reflect the influence of competition and tariff protection. The method of estimation of annual average TFP growth rates is very important. For example, the exponential growth rate based on a constant (uniform) rate of growth may not be an appropriate measure given cyclical fluctuations in the data or a sudden unusual increase in one or more components of the Divisia aggregator (e.g. a very large increase in PE or PNR). The average annual rate of change measure, which takes into account of year to year regular (continuous) changes, may be preferred to the exponential growth rate measure based on ordinary least squares estimates. In general, exponential growth rate estimates are lower than the average annual rate of change of TFP.

The analysis of TFP trends reveals a turning point. The sample time series was divided into two periods, 1961-72 and 1973-76. It was found that generally TFP growth rates decline except for some of the resource based industries. For total manufacturing the rate of TFP growth is 2.08 percent for the 1961-72 period and 1.51 percent for the 1972-76 period. However, for some of the two-digit level industries the rate declines quite substantially. For

example, for textiles the rate declines from 5.57 percent to 0.65 percent and for chemicals the rate declines from 3.11 to -2.34 percent.

With reference to our productivity study, as mentioned above, it is very important to note that in most of the other studies productivity growth rates were also found to decline in the early 1970s. The exceptional trend of the few resource based industries observed here has not been found elsewhere. A productivity decline is of particular concern to economists and policy analysts given Canadian competition with other industrialized countries. Further study of the decline in TFP is needed.

The analysis of input requirement per unit of output (factor intensity) reveals that there are substantial variations in the use of energy, renewable and non-renewable resources across industries and over time. The major features of factor intensity are that L, E and R intensity decline almost until the end of the sample period. The capital intensity shows a pattern of considerable fluctutations over time, while non-renewable resource intensity moves roughly the opposite way. It is also found that the aggregate input requirement declines, with some of the resource intensive industries displaying slower rates of decrease.

The above productivity results were based on the conventional TFP measure which assumes constant returns to scale, an assumption usually rejected by our data.

Parametric productivity measures allowing for non-homotheticity , and so consistent with the data, were determined for total manufacturing only. Throughout the period, the parametric productivity measure is smaller than the conventional TFP values. This difference arises because the productivity measure allows for economies of scale and may not account for residual factors included in conventional TFP measure. Like the conventional TFP, the parametric measure also declines in the last two years.

Some econometric problems arose in the simulation study. Those problems are dealt with in Chapter 7. It is found that the simulated effects of energy, renewable and non-renewable resource price increases on input demand and unit cost of production are considerable and these effects vary widely across two-digit industries and the total manufacturing sector.

It is found that the use of E, R or NR is reduced in response to own price increases. It follows from the simulation results that energy price increases usually increases employment. With capital and energy being substitutes or complements, increases in PE may imply either greater capital intensity or a reduction in capital intensity.

The simulated effects of energy price increases in this study and the Denny et al. (1978) study are very close, although for other inputs the results differ considerably. For example, the effect of increase in PE on both L and K

from this study are much smaller than those of Denny et al. Even though the percentage changes are smaller, the effects are not unimportant.

It is very important and interesting to note the simulated effects of energy and resource price increases on the average cost of production. It is found that for a given percentage increase, the effects of energy price increases on average cost of production are much less than the effects of renewable and non-renewable resource price increases of the same percentage. Resource price increases generally imply increased use of labour but the impact on capital and energy use is mixed.

The regional implications of the simulated results are also important. For example, increases in the price of renewable resources would tend to have a greater effect on manufacturing in the British Columbia region, while, increases in PE may affect the Ontario region more. Similarly, increases in PNR influences manufacturing costs more in the province of Alberta.

The empirical results presented in Chapters 5, 6, and 7 have important policy implications as indicated in those chapters. In general energy and resource price changes may have considerable impact on input use in manufacturing, particularly on employment. It is important to note that renewable and non-renewable resource price changes will have more impact on input demand and unit cost of production than energy price changes. Therefore, increases in agriculture,

forestry or mineral resource prices will have a greater effect on manufacturing than energy price increases.

The low value of price elasticities of demand with respect to R and NR means that changes in their prices will largely translate to higher costs. In particular, these results are consistent with the complementarity of L, NR and K, R implying that resources are required to be used with labour and capital.

Finally, inspite of the limitations of our study (e.g. small size of the sample, multicollinearity etc.) we have been able to demonstrate the role and use of energy, renewable and non-renewable resources in Canadian manufacturing production. However, given that we have excluded other materials from our specification of the production function, a further study may consider a six input model including other materials as a factor of production. Moreover, some of the important factor augmenting aspects such as technical progress, learning by doing, induced innovation etc. are yet to be investigated fully.

In addition to the above consideration, any future study might focus on a particular industry and deal with the demand for still more specific resources. For example, the demand for certain agricultural products or fish by the food industry, that of forestry products by the wood industry and similarly, the demand for any specific mineral resources (that is, iron ore, non-metallic, etc.) by the metal

fabricating industry. The results of this study suggest the potential for a variety of more intensive analyses focusing on resource inputs by resource using industries. Also, the econometric problems such as autocorrelation, multicollinearity, the power of the test statistics such as the likelihood ratio, and the F and the Wald tests in this particular application should be investigated further. In addition, a parametric productivity study for all industries would be desirable.

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Appendix 1. Sources of Data and Construction of Variables

The problems of measurement of variables are discussed in Chapter 3. A detailed description of the sources of data and construction of variables are provided in this Appendix. A list of the names of the sources of data and their catalogue numbers in parentheses are given as follows. Only catalogue numbers will be referred to in this discussion of the data sources.

Data Sources

Statistics Canada	Catalogue Numbers	Title Date
SC	(13-522)	Fixed Capital Flows and Stocks, Manufacturing, Canada (1926-1960), Methodology, February, 1967.
SC	(13-568)	Fixed Capital Flows and Stocks (1926-1978).
SC	(14-201)	Aggregate Productivity Measures.
SC	(15-508E)	Input Output Structures of the Canadian Economy (1961-1974).
SC	(15-509)	Input Output Structure of the Canadian Economy (1961-1974) (constant dollars).
		Revised Input Output Tables

(1971-1976), Input Matrix, Provided by Statistics Canada on request.

SC (31-003) Capacity Utilization in Canadian Manufacturing.

SC (31-201) (31-203) General Review of the Manufacturing Industries of Canada.

SC (57-202) Energy Statistics: Services Bulletin.

SC (57-202) Electric Power Statistics, Vol. II.

SC (57-207) Detailed Energy Supply and Demand in Canada.

SC (57-506) Consumption of Purchased Fuel and Electricity by the Manufacturing, Mining and Electrical Power Industries, 1962-1974.

SC (61-208) Corporation Taxation Statistics.

SC (62-202) Prices and Price Indexes.

SC (62-528) Industry Selling Price Indexes.

SC (62-543) Industry Selling Price Indexes, Manufacturing, 1971=100.

SC (71-001) The Labour Force.

SC (72-002) Employment Earnings and Hours.

SC (72-204) Earnings and Hours of Work in

Manufacturing.

Note: The names of other sources with dates are given in the references.

In order to estimate the cost or production function and the input demand models specified in Chapter 2, we need to construct the following variables.

X_i =Quantity of the i-th input

P_i =Price of the i-th input

Q =Output of the industry

S_i =Cost share of the i-th input

C =Total cost of production

The description of the data sources for each variable and the procedure of its construction are discussed below.

A.1 Input and Output Prices

A.1.1 Capital

Capital stock data for the Canadian manufacturing industries can be obtained from the following sources:

(i) SC (31-201) and SC (31-203) and

(ii) SC (13-568)

In the first source (i), data for value of shipments (VS), wages and salaries (WS), cost of raw materials supplies (CM), cost of fuel and electricity (CE) as well as other relevant data are available. From these variables the value of capital (VK) can be obtained as a residual measure.[1]

VK=VS-WS-CM-CE

As well, the net change in inventories (INV) can be

calculated using data for value-added (VA).

INV=VA+CE+CM-VS

which can then be used to obtain gross output.

The value of capital (VK) is deflated by an investment deflator and adjusted by a capacity utilization rate from SC (31-003). The second source (ii) provides data for mid-year net stock both in current and constant dollars. These data are adjusted by utilization rate as available from SC (31-003) and used as measure of capital.

Regional energy demand studies by Fuss (1975) and McRae (1978) use a residual measure for capital input. The residual measure is used because capital data are not available at the regional level. However, there are several difficulties with such a measure:

(i) There may be differences in profits in different years.

(ii) There are problems with inventory valuation adjustments.

(iii) There are problems due to unknown components.[2]

Data in the second source are more recently updated, and are available nationally for the total manufacturing sector as well as for all two-digit level industries. The calculation of these data is based on a perpetual inventory method.[3] This study uses capital stock data from the second source since regional production technologies are of secondary importance.

Since the major interest is in capital services, an adjustment to the capital stock data is desirable. However, an adjustment may create some problems. For example, one may use the capacity utilization rate (u) to adjust capital stock data. But in calculating u, output is involved and this will introduce biases.[4] Because of this circularity problem in calculating u, adjustment of capital will be avoided on the argument that use of energy and resources as separate inputs picks up the utilization aspect. Hence these variables will also serve as proxies for the utilization factor. In other words, the more the use of energy and resources the greater will be the utilization of capital and inputs.

A.1.2 The Rental Price of Capital

In constructing the rental price of capital we have followed the methodology of Christensen and Jorgenson (1969) as was done by Berndt (1979). We classify three types of capital stock as:

(1) Machinery and equipment (ME),

(2) Engineering structures (SE),

(3) Building structures (SB).

We define

PKME=Rental price of capital machinery and equipment.

PKSE=Rental price of capital engineering structures.

PKSB=Rental price of capital building structures.

The formula for PKME is

$$PKME = ((1-Eitx*ZE-K+YE)/(1-Eitx))*(Psm_{t-1}*RREAL+Psm_t*.1392)+Psm_t*Proptx$$

Where,

Eitx=Effective tax rate of the corporate income tax.

ZE=Present value of the depreciation allowances of a dollar's investment in machinery and equipment.

K=Rate of investment tax credit.

YE=Adjustment of the capital rental price for equipment and machinery, it reflects the fact that the investment tax credit K will reduce the base on which the depreciation (capital cost) allowances are computed.

Psm_t=The implicit investment deflator for ME.

Psm_{t-1}=Psm at the previous year.

RREAL=Real rate of return.

.1392=The rate of economic depreciation of ME (assuming a 20 year life span for all ME, i.e. 95 percent is depreciated after 20 years when the rate of depreciation is .1392).[5]

Proptx=Property Tax=Property taxes paid/Net value of fixed assets including land.

For structures the formulae are similar. For engineering structures, SE,

$$PKSE=\frac{(1-Eitx*ZS-K+Ys)}{(1 - Eitx)}*(PSE_{t-1}*RREAL+PSE_t*.0582)+PSE_t*Proptx$$

where

ZS=Present value of depreciation allowances of a dollar's investment in engineering structures.

YS=Adjustment to the capital rental price of engineering structures (SE).

Pst_t=The implicit investment deflators in 1971=100 for structure (SE).

Pst_{t-1}=Pst at the previous year.

.0582=The rate of economic depreciation in structures.

For buildings,

$$PKSB=\left(\frac{(1-Eitx*ZS-K+YS)}{1 - Eitx}\right)(Pst_{t-1}*RREAL+Pst_t*.0582)+Pst_t*Proptx$$

where

Pst =The implicit investment deflator in 1971=100 for building structures.

Pst =Pst at the previous year.

So far we have outlined the formulae for constructing the rental price of capital. The sources of data for the variables involved in the calculation of PK (i=ME, SE, SB) and the aggregate rental price PK are as follows:

Eitx: The effective rate of corporate income tax. For the years 1961-1965, this series was taken from Jenkins (1972), Table 71, p.209; for the period 1966-1974, the data were taken from Jenkins (1977) as follows,

Eitx=Income taxes paid (Table D-7)/Economic income including inventory revaluations (Table D-14).

Since Jenkin's study only went up to 1974, values for 1975 and 1976 were extrapolated. Since the series did not seem to have any definite trend (up or down), the mean of the last three years observations (1972-74) were used as values

for 1975 and 1976. This procedure was utilized by Berndt (1979).

ZE ans ZS: The present value for depreciation allowances of a dollar's investment in SE and SB respectively. This is computed using the formulae for declining balance depreciation for the years 1961-70.

$$ZE,\ ZS=(1/T/(R+1/T))(1-e^{-(R+1/T)T}) \qquad .$$

where

R is the rate of discount (assumed to be 10 percent) and T is the economic life of the asset (assumed to be 13.45 years).[6] Allowance was made for the changes in tax law of 1971. ZE was found to be .6777 for 1971 and .8678 for 1972. The corresponding ZS figures were found to be .1643 for 1971 and .1536 for 1972. For a detailed description see Berndt (1979).

RREAL: This is after tax real rate of return adjusted for inventory valuation allowances. For 1961-64 the data were taken from Jenkins (1972), Table 63, p. 187. The 1975 and 1976 values were not available but since the series does not have any specific trend, the mean values of the last three years (1972-74) were taken for 1975 and 1976. However, for the total manufacturing sector RREAL was available for these two years and were obtained from "Two Cheers For The Eighties", Economic Council of Canada, Sixteenth Annual Review, (1979).

Proptx: The effective rate of property tax, defined as

Proptx=Property taxes paid/Net income of fixed assets including land

These data were taken from Jenkins (1972) for 1961-65 (Table 64, for property tax and Table 59 for net income of fixed assets including land) and from Jenkins (1977) for the years 1965-74 (the ratio of data in Table D-8 to that in Table C-3). 1975-76 values were set at the mean of the last three years (1972-74).

Other variables in the rental price formula are:

K=Rate of investment tax credit

YE=The product of K, Eitx and ZE. The corresponding variable for structures YS is obtained as a product of K, Eitx and ZS.

Data on the investment tax credit were available since 1971 for the Province of Ontario and since 1975 for the other provinces. However, in order to obtain national data for the years 1971-73, appropriate adjustment has been made to Ontario's rate for those years. The sources of the data is SC (61-208).

With PK (i=ME, SE, SB) calculated from the rental price formulae above and their corresponding quantities QK (i=ME, SE, SB), we have obtained the aggregate Divisia index for capital rental price PK and a measure of the total cost of capital (CK). The latter is calculated as:

$$CK = QK * PK$$

where $QK = (\sum_i P_{ki} * Q_{ki})/PK$

QKME=Mid-year net capital stock in machinery and equipment in millions of constant 1971 dollars.

QKSE=Mid-year net capital stock in engineering structures in millions of constant 1971 dollars.

QKSB=Mid-year net capital stock in building structures in millions of constant 1971 dollars.

These data were taken from SC (13-568). These capital stock data were calculated using a perpetual inventory method. For methodology see SC (13-522).

A.2 Labour

A.2.1 Labour Input

In Chapter 3.A.1 it is argued that man-hours worked (MHW) is the ideal measure of labour input. As an alternative to MHW one may have to use man-hours paid (MHP). For example, Fuss (1977) used MHP as the labour input. Both series were determined and the methods are discussed in this section.

The total labour force in production consists of production workers (blue collar, non-production or salaried employees (white collar), and proprietors (self-employed owner-operators). Sources of data for each type of worker, wage rate per worker and the calculation of total cost of labour will be discussed below.

Sources of MHW Data

Production workers: Data provided by Statistics Canada on request.

Salaried employees: Data provided by Statistics Canada on request.

Proprietors (self-employed): Data available from SC (31-203).

Sources of MHP Data

Production workers: Data available from SC (31-203)

Salaried employees: Not available from SC (31-203), but can be calculated in the following manner.

MHP_s=Man-hours paid for salaried workers, calculated as

MHP_s=The annual payroll (salaries)/Average hourly earnings of salaried workers

Annual payroll information is given in SC (31-203) and an annual survey SC (72-204) provides data for average hourly earnings for salaried employees (AHEs) during the period 1961-69. However, this survey was discontinued in 1969, and AHEs data for later years is approximated as:

AHEs=Average weekly earnings (AWEs)/Standard work week (SWHs)

AWEs data were taken from SC (72-002).

Data on SWHs were collected from the occasional labour costs surveys of manufacturing. As those data are not reported in the labour costs publication the data were provided by Statistics Canada on request. However, those data were available for the years 1971 and 1976 only. For the intermediate years the SWHs were calculated by linear interpolation.[7]

The quantities and prices for production and salaried labour in manufacturing can then be defined as follows:

MHP_m=Man-hours paid, production workers

AHE_m=Wages of production workers/MHP

=Average hourly earnings of production workers.

AHE_s=Average weekly earnings of salaried employees (AWE_s)/SWH_s

=Average hourly earnings of salaried employees.

MHP_s=Salaries of salaried employees/AHE_s

Data on the number of proprietors (self-employed) are avialable from SC (31-203) and is used as a basis for completing the labour data as described below.

Since MHW data is preferred to MHP data and since MHW data were eventually provided by Statistics Canada, that was employed as the measure of labour services in this study. Thus, labour input was measured as total man-hours worked by production workers, non-production workers (salaried employees) and proprietors (self-employed) instead of man-hours paid. The cost of labour was measured as total labour compensation (TLC). Total labour compensation includes all payments in cash or in kind by employers to persons employed as remuneration for work, including wages, salaries and supplementary labour income and estimated rreturns to self-employed workers. Statistics Canada (14-201) provides TLC according to this procedure.

A.2.2 Construction of Labour Prices and Labour Compensation

Let us define the following variables:

HW=Total man-hours for production workers.

HS=Total man-hours for non-production workers.

HP=Total man-hours for proprietors (self-employed).

Data on HW and HS were provided by Statistics Canada on request. Similar information for proprietors is unavailable but SWH data were provided by Statistics Canada on request.

The construction of HP variables depends on:

(i) the number of proprietors, taken from SC (31-203) and

(ii) the SWH data provided by Statistics Canada.

However, the SWH series was not complete for the period 1961-76. As mentioned before, Statistics Canada provided data for the years 1971 and 1976 and the data for intermediate years were obtained by linear interpolation. For the earlier years (1963-69) these data were taken from SC (72-204). This publication was not available for the years 1961 and 1962, the data for these two years were obtained using 1960 and 1963 data (by interpolation).

Proprietors salaries is an imputed income which is based on the assumption that they work the same number of hours as the salaried employees, using the standard work week in hours (SWH) of the salaried employees as obtained above, HP is calculated as follows:

HP=number of proprietors 52 SWH

where 52=number of weeks in a year.

A.2.3 Other Variables

WW=Wages paid to production workers, millions of current dollars.

SS=Salaries paid to salaried employees, millions of current dollars.

These data were taken from SC (31-203).

It may be noted that WW and SS are only direct payments to employees including income tax withheld but excluding fringe benefits. Data on fringe benefits are taken from the following sources:

(i) "Fringe Benefit Costs in Canada", various issues, The Thorne Group Limited, Management Consultant.

(ii) "Employee Benefit Costs in Canada", various issues, Thorne Riddel Associates Ltd. Management Consultant.

It should be noted that fringe benefits, from the above sources, do not overlap with data from Statistics Canada (31-203).

A.2.4 Price of Labour

Given the data we have discussed so far, the prices of production workers (PW), salaried employees (PS) and proprietors can be defined as follows:

(i) PW=(WW+(FB WW))/HW

where FB=Fringe benefits as percentage of gross wage bill.

(ii) PS=(SS+(FB SS))/HS

(assuming same FB for production and salaried workers)

(iii) PSP=price of proprietors

We assume that PSP=PS, of non-production employees.

The prices obtained as above, include supplementary benefits (through fringe benefits) and hence total labour compensation can be obtained as follows:

CL(W)=PW HW, labour compensation, (production workers).

CL(S)=PS HS, labour compensation, (salaried employees).

CL(P)=PS HP, labour compensation, proprietors.

TLC can be obtained by aggregating over CL(W), CL(S) and CL(P). As mentioned earlier, aggregation was done by the Divisia index.

Given quantities (as hours) HW, HS, HP and prices (wage and salary rates per man-hour) PW, PS and PSP respectively an aggregate Divisia price index of labour (PL) and cost CL (as TLC) can be constructed such that:

$C_L = PL*QL$, where

$QL = (\sum_i P_i * H_i)/PL \quad i=W,\ S,\ P \quad (S=P)$

A.3 Energy Data

A.3.1 Sources of Energy Data and Conversion into Output BTUs

The following are the main sources of energy data for Canadian manufacturing industries:[8]

(i) SC (57-506)

(ii) SC (57-002)

(iii) SC (57-202) Volume II

In Chapter 3.A.3 the necessity of transforming various types of natural units of energy quantities into output BTUs

is explained. The transformation of the data is as follows:[9]

(a) the conversion of the natural unit into input BTUs and then to output BTUs.

(b) the disaggregation of oil into its components, namely, heavy fuel oil, light fuel oil, kerosene and diesel oil, and the aggregation of anthracite, sub-bituminous, bituminous, imported bituminous, lignite and coke into coal.

Because of this transformation all quantities are measured in millions of output BTUs and all corresponding prices are measured in dollars per million output BTUs. The output BTUs are obtained as follows:

(1) The conversion of natural units into input BTUs using conversion factors reported in Table A.1.

(2) The conversion of input BTUs into output BTUs using a factor which captures the relative efficiency of energy conversion among different fuel appliances used in the same end-use. Efficiency factors are reported in Table A.2.

TABLE A.1

CONVERSION FACTORS FROM NATURAL UNITS TO INPUT B.T.U. UNITS

FUEL		CONVERSION FACTOR (Input B.T.U./Natural Unit)
1. Electricity		3.412 BTU/MKWH
2. Natural Gas		1000-1060 MMBTU/MMcf
3. L.P.G. (Liquified Petroleum Gas)		4.095 MMBTU/Barrel
4. Gasoline		5.222 MMBTU/Barrel
5. Oil	Heavy fuel oil	6.2874 MMBTU/Barrel
	Light fuel oil	5.8275 MMBTU/Barrel
	Kerosene	5.6770 MMBTU/Barrel
	Diesel oil	5.8275 MMBTU/Barrel
6. Coal	Anthracite	25.4 MMBTU/Ton
	Imported Bituminous	25.8 MMBTU/Ton
	Bituminous	25.2 MMBTU/Ton
	Sub-Bituminous	17.0 MMBTU/Ton
	Lignite	13.2 MMBTU/Ton
	Coke	24.8 MMBTU/Ton

Source: 1. SC (57-207)
2. McRae R.N. and Alan R. Webster "Regional Energy and Production Data for Canadian Manufacturing Industries", Working Paper #78-6, Canadian Energy Research Institute July, 1978.

Notes: MMBTU = Millions of B.T.U.
MKWH = Thousands of KWH
MMcf = Millions of Cubic Feet

NATURAL GAS CONVERSION FACTOR

1962	1060
1963	1050
1964	1035
1965	1020
1966	1010
1967 - 1974	1000

The conversion factor for 1975 and 1976 are taken to be the same as 1967-74.

Source: McRae and Webster (1978)

TABLE A.2

CONVERSION FACTOR OUTPUT B.T.U./INPUT B.T.U.

FUEL	OUTPUT B.T.U./INPUT B.T.U.
Electricity	1.00
Natural Gas	.85
LPG	.85
Gasoline	.20
Heavy Fuel Oil	.87
Light Fuel Oil	.82
Kerosene	.82
Diesel Oil	.26
Coal	.87

Source: McRae and Webster (1978).
Original Source: Canada, Department of Energy, Mines and Resources.
Energy Demand Projections: A Total Energy Approach, Report ER-77-4, Ottawa 1977.

The data for oil are available as aggregate fuel oil for the years 1962-72 and in disaggregated form for the years 1973-76. Since there are substantial differences in conversion factors[10] for fuel components (kerosene, light fuel oil, heavy fuel oil and diesel oil), it is necessary to first disaggregate fuel oil into four components for the years 1962-72, then to convert into output BTU units and finally to aggregate these four components. This determination is based on the quantity shares of oil components assuming that for each industry the quantity share for each component is constant over the period 1962-72. The component shares are calculated as an average using the 1973 and 1974 data for each industry. These shares are shown in Table A.3.

The data for coal are separated for sub-bituminous, imported bituminous, bituminous, lignite, anthracite and coke for the years 1962-72, but these are only available as an aggregate for the years 1973-76. It is necessary to disaggregate the coal and coke data for 1973-76 because of the differences in the conversion factors for natural units to input BTUs for each of the coal components.[11] Again the disaggregation is done using the quantity shares of the use of coal components. However, because the trend of the use of coal components declined sharply after 1970, the share of each type of coal is calculated as the proportion of each component in the total coal and coke figure for 1972 instead of taking an average of over several years.

TABLE A.3

AVERAGE FUEL SHARES
(1973 and 1974)

INDUSTRY	KEROSENE S1	DIESEL OIL S2	LIGHT FUEL Oil S3	HEAVY FUEL Oil S4
Tobacco	.0028	.0478	.0160	.9334
Rubber	.0012	.0087	.1543	.8358
Leather	.1411	.0540	.2861	.5188
Textiles	.0180	.0014	.0658	.9148
Knitting	.0612	.0166	.2467	.6755
Clothing	.1039	.0245	.5214	.3502
Wood	.0758	.5152	.1513	.2577
Furniture	.0773	.0626	.7434	.1167
Paper	.0027	.0056	.0262	.9655
Printing	.0926	.0091	.5331	.3652
Primary	.0203	.0223	.1110	.8464
Metal fab.	.0618	.0803	.4292	.4287
Machinery	.0144	.0432	.4218	.5206
Transport	.0279	.0543	.3373	.5805
Electrical prod.	.0046	.0129	.2922	.6903
Non-metallic	.0013	.0810	.0623	.8454
Petroleum	.0055	.0867	.3334	.5744
Chemicals	.0118	.0085	.0538	.9259
Misc.	.0180	.0110	.4396	.5314
Food	.0640	.1135	.1953	.6272
TOTAL	.0167	.0392	.0898	.8543

TABLE A.4

SHARE OF COAL COMPONENTS (1972)
(QUANTITY SHARE)

INDUSTRY	ANTHRA-CITE S1	CANADIAN BITU-MINOUS S2	IMPORTED S3	SUB BITU-MINOUS S4	LIGNITE S5	COKE S6
Tobacco	0	0	1	0	0	0
Rubber	0	0	1	0	0	0
Leather	.2558	.7442	0	0	0	0
Textiles	.0174	0	.8511	.0086	.1229	0
Knitting	0	0	0	0	0	0
Clothing	0	.3518	0	0	0	.6842
Wood	.0110	.6112	.3730	0	0	.0048
Furniture	.0205	.5359	.3836	.0057	0	.0544
Paper	0	.3158	.3692	0	.2499	.0650
Printing	0	0	0	0	0	0
Primary	.2429	.1574	.3672	.000013	.0050	.2276
Metal fab.	.0857	.8458	.0624	0	.0037	.0024
Machinery	.0605	.0457	.0838	0	0	0
Transport	.00002	0108	.9889	0	0	.0001
Elec. prod.	.1426	.8574	0	0	0	0
Non-met.	0	.2103	.7701	.000057	.0071	.0125
Petroleum	0	0	0	0	1	0
Chemicals	.1540	.0160	.8277	0	0	.0022
Misc.	.0057	.4950	.4202	0	0	.0790

These shares are then used to disaggregate coal into its components for 1973-76. Similarly, we have converted natural units into input BTU units over the period 1962-72.

A.3.2 Own Generation of Electricity

Total consumption of electricity (TCE) by the manufacturing industry includes the amount of electricity purchased (EP) and the amount generated for own use (OGE). Quantities of EP in MKWH[12] are available from SC (57-506) for each of the twenty two-digit industries and for the total manufacturing sector, but total consumption data are not explicitly available for all of these two-digit industries since the amounts generated for own use are not always reported. However, TCE data are available for the sub-sectors of some of the two-digit level industries from SC (57-202). These sub-sectors and their weight in the total sector for those industries are shown in Table A.5. Information on these sub-sectors can be used to derive estimates of OGE and so of TCE by industry.

TABLE A.5

WEIGHTS OF SUB-SECTORS RELATIVE TO THE INDUSTRY

INDUSTRY	CODE TWO DIGIT	SUB-SECTORS	SIC CODE #	% WEIGHT OF SUB-SECTORS	% WEIGHT OF WHOLE INDUSTRY
Paper	10	Pulp & Paper	10-2710	5.428 (69.51%)[a]	7.809
Non-metallic	17	Cement Manufac-turing	17-3520	.361 (11.86%)	3.043
		Abra-sives	17-3570	.128 (4.21%)	
Primary	12	Iron & Steel Mills	12-2910	3.054 (38.32%)	7.970
		Smelting & Ref.	12-2950	2.707 (33.96%)	
Petroleum	18	Petro. Ref.	18-3651	3.898 (96.39%)	4.044
Chemicals	19	Indust.	19-3782	.898 (14.32%)	6.270
		Chem.	19-3783	1.073 (17.117%)	
Other Manufact-uring	--	--	--	--	--

Source: SC (62-543) Manufacturing, 1971 = 100, 1956-76

a: The figure in brackets is a sub-sector weight as a % of the whole industry weight.

The SIC two-digit classification code number, the name of the sub-sector, SIC four digit code numbers, sub-sector weight as a percent of the total two-digit industry selling price index and whole industry weight as a percent of the total manufacturing sector industry selling price index are shown in columns 2, 3, 4, 5 and 6 respectively in Table A.5. It is evident from Table A.5 that sub-sectors falling under Paper (10), Primary (12) and Petroleum (18) industries are fairly representative of those industries in that they account for about 70 percent or more of industry output. The sub-sector of the Non-metallic (17) and Chemicals (19) reporting TCE are poor proxies for their industries.

Given the above situation, the problem is how to obtain own generation of electricity data for all the two-digit manufacturing industries. There are three possible ways to do it :

1(a) Take "Pulp and Paper', "Iron and Steel Mills" plus "Smelting and Refining" and "Petroleum Refineries" as representing Paper (10), Primary (12) and Petroleum (18) industries respectively.

1(b) Then subtract the quantities of electricity (TCE, representative of the sub-sectors of these three industries from the TCE quantities of the total manufacturing sector and allocate these residuals (the TCE by 17 industries) among these 17 industries in proportion to their purchased amounts of electricity which are available from SC (57-506)

2(a) Do the same as above but also include "Industrial Chemicals" as representing "chemicals" industry.

2(b) Do the same as in 1(b) but allocate residuals among the 16 industries.

3(a) We can also include the sum of "Cement manufacturing" and "Abrasives" as representing the "Non-metallic" industry.

3(b) Do the same as in 1(b) but allocate residuals among the 15 industries.

Taking "Abrasives" and "Cement manufacturing" as representative of Non-metallic it has been found that OGE becomes negative. This implies that these two sub-sectors fall far short of representing the whole industry. Therefore, the third possibility can be ruled out. As for the second possibility it is quite obvious from Table A.5 that "Industrial Chemicals" very poorly represent the Chemicals industry (even less than one-third of the whole industry). This may lead to under estimates of the amount of OGE. Therefore, the OGE for each of the seventeen industries, other than Paper, Primary and Petroleum industries, has been allocated by procedure 1 above. The quantities of OGE so obtained were then converted into output BTU units. It has been assumed that OGE has the same unit price as that of EP.

Given the quantities, as obtained above, and the cost of individual energy components, a unit price for each type of energy is calculated as follows:

$PE_i = Cost(E_i)/QE_i$

where

PE_i=Price of i-th energy component.

E_i=i-th energy quantity.

i=Oil (O), natural gas (NG), LPG (LG), gasoline (G), electricity purchased (EP), electricity own generated (OGE) and coal (QCL)

Seven pairs of prices and quantities have been determined. These are :

(PO, QO), (PNG, QNG), (PLG, QLG), (PG, QG), (PEP, QEP), (POGE, QOGE), (PCL, QCL)

where QE =Quantity of the i-th energy type in millions of BTUs. Since PE is the price per unit of energy type i, it is also the unit cost to the optimizing agent.[13] With these PE and QE we constructed an aggregate Divisia price index PE and an implicit quantity QE, where the cost of energy CE can be obtained as

CE=PE*QE, such that

$QE = (\Sigma PE_i * QE_i)/PE \quad i=O, NG, LG, G, EP, OGE, QCL$

Since a simple weighted average of the PE implies perfect substitutability while the Divisia index does not[14], it is, therefore, an ideal method to be used.

The energy sources mentioned above provide energy data for the years 1962-76. The values of PE and QE for 1961, therefore, were obtained by extrapolation using a regression technique. This technique will be discussed in the next section.

A.3.3 Extrapolation for Missing Observation

The sample size in this study is sixteen years covering the period 1961-76. Energy data are not available before 1962. Therefore, we are missing the PE (1961) and CE (1961) observations. Since the corresponding observations for all other associated variables are available and since the sample size is not large, extrapolating missing values for these two variables is preferred to dropping the year altogether.

There are different methods of extrapolation.[15] The simplest method would be to make a linear extrapolation. But since for a small sample each and every observation is quite important to the estimated results the extrapolation should be done as accurately as possible. One of the methods of extrapolation is to find a series which is reasonably correlated with the series to be extrapolated. In our case such a series is the total cost of energy (CEE) which is available from SC (31-203) and goes back to 1961. Since our purpose is to extrapolate the aggregate energy price (PE) for the years 1961, CEE can be taken as related to PE. We, therefore, specificy a relationship with PE as the dependent variable and CEE and t, a time trend, as independent variables. That is,

$$PE=f(t, CEE) \qquad (1)$$

It is further assumed that the relationship may be closely approximated with either a linear or a non-linear regression model.

Given the fact that there was a sharp rise in energy prices around 1973, a non-linear relationship between PE and t is to be expected. The linear and non-linear models are specified as follows:

(a) Linear model

$$PE=\alpha+\beta_1 t+\beta_2 CEE+u_1 \qquad (2)$$

where α_0, β_1, β_2 are unknown parameters and u_1, is the disturbance term.

(b) Non-linear model

$$PE=\alpha_1 e^{\beta t}\ CEE^{\gamma} u_2 \qquad (3)$$

where α_1, β, γ, are unknown parameters and u_2 is the disturbance term.

Taking logarithms of both sides of (3), we have

$$\log(PE)=\log(\alpha_1)+\beta t+\ \gamma\log(CEE)+\log(u_2)$$

Regression models (2) and (3) were used to extrapolate PE (1961) and CE (1961) for the total manufacturing sector and for all two-digit level industries. Once the parameters are estimated, the values of CEE (1961) and t (1961) are substituted in the regression equation and the value of PE (1961) is obtained.

The choice between the two estimates of PE (1961) (based on models 2 and 3) was mainly based on the consistency with PE (1962). However, consistency with a longer trend was also a criterion. The model used for each industry is indicated in Table A.6.

TABLE A.6

INDUSTRY AND MODEL FOR EXTRAPOLATION

LINEAR	NON-LINEAR
Food and Beverages	Rubber
Tobacco	Leather
Wood	Textiles
Furniture	Knitting
Primary	Clothing
Metal Fabricating	Paper
Electrical Products	Printing
Non-metallic	Machinery
Total	Transportation
	Petroleum
	Chemicals
	Miscellaneous

A.3.4 Cost of Energy

The calculation of the cost of energy is as follows:

$$CE=PE*QE \quad (4)$$

where $QE=(\sum_i PE_i*QE_i)/PE$

$\sum_i PE_i QE_i$ is the aggregation over seven components treating OGE separately. However, this does not include the cost of other fuels (COF) available from SC (57-506). Again CEE (available from SC (31-203), costs of electricity and supplies used) does not include the cost of OGE. Therefore, the actual cost of energy (CEA) should be either:

$$CEA=CE+COF \quad (5)$$

or

$$CEA=CEE+\text{cost of OGE} \quad (6)$$

The difference between (5) and (6) is usually very small. However, for some of the industries the difference is significant for the years 1975 and 1976. Equation (6) is used for calculating the actual cost of energy in this study. The reason for choosing (6) instead of (5) is that quantity data are unavailable for COF.

Alternatively, the cost of OGE (1961) can be obtained as:

$$COGE\ (1961)=POGE\ (1961)*QOGE\ (1961) \quad (7)$$

It is assumed that the price of OGE is the same as the price of electricity purchased (EP). While the price of electricity is not available for 1961, the price of electric power (Pelect 1961) could be obtained from the "Input Output Table" in the following manner:

Pelect (1961)= Value of electric power at current dollar/Value of electric power at constant dollar.

Since the prices for 1961 so obtained is greater than the 1962 prices already available (and electricity prices during the early 1960's were quite stable), Pelect (1961) was calculated instead as the average of the prices available for 1962, 1963 and 1964. Using this average price for Pelect (1961), the CE (1961) is calculated as

CE (1961)=CEE (1961)+COGE (1961).

A.4.1 Resources:Renewable and Non-Renewable

Aggregate resource input or quantity and corresponding resource price measures are needed.[16] Different industries use different types of renewable and non-renewable resources. A resource input may be considered as a highly specific input consisting only of sub-components of similar types of primary, or slightly processed resources. For example, "grains" itself may be treated as a resource input consisting of sub-components of different types of crops such as wheat, barley, oats, rye, etc. Similarly, "forestry products" consist of various types of forestry related products such as logs and bolts, pulp wood, poles and pilings etc. However, in general any specific industry uses more than one such highly specific resource. For example, grains, live animals, other agricultural products, fish landings, meat products, dairy products and fish products are collectively renewable resources used by the food

industry. Similarly, metallic minerals and non-metallic minerals are non-renewable resources.

In aggregation, the basic resource components are aggregated into a sub-aggregate; for example, the category, "grains" is a sub-aggregate of the different types of crops mentioned above. As well, a corresponding price index is constructed for this sub-aggregate. Then in the second-stage, sub-aggregates are aggregated to obtain the required aggregate resource input. As before, the Divisia aggregation procedure is used. All resource data are taken from the input-output tables.

A.4.2 Prices of Resources

It is possible to obtain resource prices in two ways.

(a) From the Input-Output Tables an implicit price index for each individual resource can be obtained as follows:

PR_i=Value of resources in current dollars/Value of resources in constant dollars

where PR_i=Price of a resource or a resource product of the i-th type.

(b) For each individual resource a price series must be constructed. It can be based on the quantity of the i-th produced resource (Q_i) and the corresponding value (V_i) of that resource. A selling price of the resource is obtained as:

$PSP_i=V_i/Q_i$, the per unit selling price. This PSP could be treated as the price of a resource or a resource

product for the purposes of this production study. The reason for interpreting this as a price is that the selling price of a resource to its producer is the buying price of the resource to the industry using the resource as an input.[17] Humphrey and Moroney (1975) adopted this procedure for constructing resource prices for U.S. manufacturing. For this study resource prices as obtained from the first source (input-output table, providing industry specific prices) and are preferred to the second source (various publications of Statistics Canada) which provides a general price and not an industry specific price. It should be noted that the values of resources (in constant dollars), as determined (in input-output table) are in producer's prices.

The value of the i-th renewable resource component, in constant dollars, is treated as the quantity (a real measure) of the i-th renewable resource component. Its price, PR , was defined above. The Divisia aggregate price index (PR) and the quantity index (QR) for renewable resources are obtained with these PR 's and QR 's. The cost of renewable resources (CR) is obtained as:

CR=PR *QR

where

$QR=(\sum_i PR_i * QR_i)/PR$, $i=1, 2, ---- m_1$, m_1 is the number of different types of renewable resources used by an industry.

The Divisia aggregate price index (PNR) and the quantity index (QNR) for non-renewable resources are

obtained similarly.

Finally, the cost of non-renewable resources (CNR) is obtained as follows:

$CNR=PNR*QNR$

where,

$QNR=(\sum_i PNR_i*QNR_i)/PNR$ $i=1, 2, ---m_2$, m_2 is the number of different types of non-renewable resources used by an industry.

Resource data are obtained from

SC (15-508E), 1961-74 data in current dollars

SC (15-509E), 1961-74 data in constant dollars

Revised data for (1971-76), were provided by Statistics Canada on request.

A.5 Output

A.5.1 Output Quantity

Recent Canadian studies (Denny et al., 1977, 1979; McRae, 1978; Fuss, 1977) measure output as real gross output. The total value of output (TV) is given by:

$$TV=VA+CM+CE, \quad (8)$$

where

VA=value added

CM=cost of materials

CE=cost of energy.

The real gross output at time t is Q_t, defined as:

$$Q_t=TV/PS \quad (9)$$

where

PS=output price, the industry selling price index.

In (8) CM can be broken down as:

CM=CR+CNR+COM (10)

where

CR=cost of renewable resources

CNR=cost of non-renewable resources

COM=cost of other materials.

It may be noted that other materials are inputs that have been processed further than those identified as renewable and non-renewable resources which are basically raw materials. Other materials comprise products such as paper products, newsprints, other paper stock, clothing and accessories, plastic fabricated products, industrial chemicals etc. For some of the industries the cost of other materials share are small. For example, for the primary metal industry the COM share is about 18 percent of the total cost of aggregate materials (R, NR and COM), for the wood industry this share is about 33 percent, for petroleum about 20 percent and for food 46 percent. For some of the industries COM is important and for some it is not.

In the present study TV does not include COM and is given by:

TV'=VS+INV-COM (11)

where

VS=value of shipments

INV=the net change in inventory, given by

$INV=VA+CE+CM-VS.$ (12)

Substituting (12) and (10) for INV and CM respectively in (11), we obtain

$TV_t=VA+CE+CR+CNR.$ (13)

In defining TV' in (11) it is assumed *a priori* that the marginal product of COM is independent of other inputs (i.e. other materials are separable).[18] In order to obtain a real output measure it is necessary to deflate (13) by an output price. The industry selling price index (PS) is the deflator for gross output defined in (8). The question is, can this be used for deflating (13)? Assuming that perfect competition exists in the product and factor markets, PS is a suitable deflator for (13). Therefore, real output is obtained as:

$Q_t=TV'_t/PS$ (14)

In so doing the impact of COM on the determination of a firm's selling price is ignored with an implicit assumption that COM is separable from other inputs.

A.5.2 Industry Selling Price Index PS

Industry selling price indexes are taken from the following sources:

(1) SC (62-202)

(2) SC (62-528)

(3) SC (62-543)

It may be noted that for some of the industries (namely, Rubber, Metal fabricating, Transportation, Electrical products and Miscellaneous) the price indexes are

not available from the above sources at the two-digit level but rather at the four-digit level. In those cases price indexes have been constructed as weighted indexes. For example, consider the case of the Transportation industry. PS's data for the whole period 1961-76 are available for two of the four four-digit level sub-sectors, 15-3230 and 15-3250, and their respective weights are 5.670, and 1.974 (together accounting for 7.644 of the total industry weight of 9.455). In order that these weights can be add up to unity the given weights are converted into proportions as 0.7418 and .2582 respectively. The aggregate PS is then calculated as:

PS=PS(15-3230)*0.7418+PS(15-3250)*0.2582

This is treated as the PS for the industry. Similar weights are also shown in Table 5, column 5, for example, the cases of Non-metallic, Primary and Chemicals. The PS for other industries listed above are similarly calculated.

Footnotes to Appendix 1

1. See McRae and Webster (1978), p.12

2. The problem is that differences in profit rates may be due to rent, where rent may vary depending on the monopoly power of the firm which is unknown. Therefore, differences in rent may create problem in the residual measure. Inventory valuation adjustment may create a problem in that firm may adjust its level of output by changing its inventory, where inventory valuation may be affected by the interest rate which is external to the firm. The interest rate may increase or decrease which in turn will affect the valuation of inventory. Therefore, valuation of the inventory adjustment will affect capital value.

Other unknown components may involve random events or any other factors. See Berndt and Wood (1979).

3. See Statistics Canada (13-522), February, 1967.

4. See Statistics Canada (31-003).

5. When the rate of capital cost allowance is 20 percent, 95 percent of the asset's initial cost will be depreciated in 13.425 years (see Berndt 1979). This can be shown as follows:

Let

I=investment

L=Life of the asset

r=capital cost allowance

Given the capital cost allowance by the Government tax

authority, L is obtained as

$$I*(1-r)^L=0.05*I$$

or $L*\log(1-r)=\log(0.05)$

or $L=\log(0.05)/\log(1-r)=13.425$, for $r=.20$, a 20 percent capital cost allowance.

6. Life of the asset in this case can also be obtained as in footnote 5.

7. For interpolation, the following linear ralation is assumed:

$$SWH(1976)=SWH(1971)+\beta*T,$$

where β is the slope coefficient which may be positive or negative, T=1971, 72,---- 76, $\beta=(SWH(1976)-SWH(1971))/5$. For the food industry $\beta=-0.11$, given SWH(1971)=37.95, SWH(1976)=37.40. For the rubber industry $\beta=.096$.

8. Some typographical errors in the energy data source SC (57-506) were detected by McRae and Webster (1978). The energy data were obtained from them on request and were used in this study. Data for 1976 were supplied by Statistics Canada on request (since 1976 energy data were yet to be published).

9. In transforming energy data, we have followed the methodology of McRae and Webster (1978).

10. See Table A.2.

11. See Table A.1.

12. Millions of kilowatt hours.

13. See Fuss (1977).

14. Properties of the Divisia index is discussed in Chapter 3. For details see Diewert (1976).

15. For interpolation or extrapolation in regression analysis see Maddala (1977) pp. 201-207, section 10.4.

16. Physical quantities of resource components are not published. For the purpose of aggregation, heterogeneous resource components (in physical units) are converted into dollar values and deflated by the price index to obtain a real measure.

17. This provides a general producer's price of resource component and this is not industry specific. This method does not allow for the possibility of intermediaries and their markups.

18. Humphrey and Moroney (1975) make a similar assumption.

Appendix 2. DATA

Table 1: Manufacturing Input Price Indexes, 1961-76

1. FOOD

YEAR	PL	PK	PE	PR	PNR
1961	.51123	.78527	.85079	.76749	.80433
1962	.52419	.79692	.88094	.80764	.81266
1963	.53958	.81976	.88586	.79030	.81139
1964	.55901	.91277	.90254	.78869	.82066
1965	.58413	.88512	.90205	.83316	.81724
1966	.63291	.91498	.90588	.89170	.83633
1967	.68575	.89918	.91513	.89889	.85680
1968	.74322	.95304	.92871	.91013	.87717
1969	.83820	1.00435	.93176	.96646	.90118
1970	.90993	.99348	.94134	.98416	.96147
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.07611	.90917	1.05448	1.13329	1.04622
1973	1.15730	.89653	1.14665	1.48533	1.09703
1974	1.34321	.94133	1.40084	1.65718	1.25975
1975	1.59288	1.14091	1.68667	1.75783	1.45544
1976	1.80477	1.22736	2.05273	1.71639	1.59098

2. TOBACCO

YEAR	PL	PK	PE	PR
1961	.46368	.80242	.82864	.82239
1962	.47185	.79486	.89162	.81099
1963	.49573	.77370	.90126	.84392
1964	.52530	.80376	.92660	.72396
1965	.54523	.88325	.92306	.80026
1966	.57760	.83592	.90264	.93728
1967	.63157	1.24315	.87796	1.05800
1968	.73104	.88363	.92030	1.00847
1969	.80957	.90955	.87858	1.02777
1970	.90557	.93046	.91662	.99439
1971	1.00000	1.00000	1.00000	1.00000
1972	1.07056	.98510	1.02488	1.00726
1973	1.16360	.99474	1.09794	1.06970
1974	1.31368	1.05066	1.27226	1.14419
1975	1.55556	1.22834	1.50421	1.32993
1976	1.79334	1.32585	1.86808	1.36129

3. RUBBER

YEAR	PL	PK	PE	PNR
1961	.41427	.70218	.74500	.83581
1962	.42050	.68774	.78695	.82958
1963	.42196	.73891	.76533	.84504
1964	.43421	.80240	.76338	.83664
1965	.45947	.73385	.76361	.87704
1966	.46791	.79900	.77826	.87196
1967	.48206	.87536	.80268	.91959
1968	.46102	.86841	.81686	.91503
1969	.50371	.88120	.83693	.95669
1970	.90590	.92818	.92943	.97986
1971	1.00000	1.00000	1.00000	1.00000
1972	1.07626	.83613	1.03248	1.01893
1973	1.15139	.80209	1.07893	1.10864
1974	1.28947	1.16827	1.38860	1.34762
1975	1.49205	1.04128	1.55508	1.50765
1976	1.67518	1.11439	1.96928	1.57157

4. LEATHER

YEAR	PL	PK	PE	PR
1961	.53741	.66675	.93040	.76169
1962	.56347	.63651	1.00755	.81043
1963	.58845	.65788	.99704	.76437
1964	.61366	.74295	.99794	.72412
1965	.63646	1.44893	.99659	.75443
1966	.69200	.75122	.94657	.90189
1967	.74435	.80196	.97154	.87076
1968	.79340	.89421	.97517	.88452
1969	.86621	.81639	.99326	.96387
1970	.92299	.83519	1.01304	1.00999
1971	1.00000	1.00000	1.00000	1.00000
1972	1.06664	1.69592	1.11007	1.86086
1973	1.16660	.88296	1.30652	2.24299
1974	1.33128	1.41634	1.48746	1.63495
1975	1.53741	1.33305	1.55014	1.39100
1976	1.73433	1.42820	1.78815	2.00609

5. TEXTILES

YEAR	PL	PK	PE	PR	PNR
1961	.52948	.97537	.86760	.98195	.81651
1962	.55991	1.04690	.87990	1.00195	.77779
1963	.58172	.99466	.87920	1.07065	.81751
1964	.60407	1.05571	.88549	1.09897	.80110
1965	.63075	.94236	.89831	1.02088	.85183
1966	.68468	.95834	.92997	1.03705	.86812
1967	.74033	.84684	.92636	.94503	.88747
1968	.80647	.96378	.93035	.92845	.83593
1969	.88024	1.00570	.97565	.95284	.88005
1970	.94191	1.08385	.91452	1.01399	.97397
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.07252	.96752	1.06181	.98679	1.03467
1973	1.15289	1.02175	1.14268	1.30434	1.10936
1974	1.30067	1.25101	1.59253	1.81304	1.39741
1975	1.49108	1.32487	1.82207	2.19391	1.70535
1976	1.70350	1.41954	2.14594	2.17175	1.88681

6. KNITTING

YEAR	PL	PK	PE
1961	.52380	.67221	.99097
1962	.54337	.74429	.95923
1963	.56627	.72514	.93074
1964	.59361	.79990	.96725
1965	.61258	1.61809	.95485
1966	.67188	.84272	.95095
1967	.72631	.87357	.92454
1968	.78011	.97559	.93767
1969	.85859	.94377	.94516
1970	.92279	.94595	.97142
1971	1.00000	1.00000	1.00000
1972	1.08716	.93288	1.01317
1973	1.17224	.88200	1.09779
1974	1.35441	.84765	1.28571
1975	1.58368	1.01115	.95376
1976	1.78236	.99856	1.71017

7. CLOTHING

YEAR	PL	PK	PE	PR
1961	.51814	.79550	1.02674	1.01273
1962	.55038	.81763	1.00036	1.02910
1963	.57443	.91437	1.03606	1.05433
1964	.59622	.92887	1.03710	1.02921
1965	.62614	.83520	1.01409	1.11946
1966	.67825	.76009	.93341	.96533
1967	.71629	.86240	.95958	.89616
1968	.77647	.96931	.96091	.96977
1969	.84953	.99262	.96634	1.01134
1970	.90480	.95260	.98478	.92486
1971	1.00000	1.00000	1.00000	1.00000
1972	1.08182	1.03238	.98129	1.34145
1973	1.17921	.95838	.99470	1.60739
1974	1.33438	1.03371	.90969	1.48202
1975	1.53655	1.16868	1.27479	1.78841
1976	1.72866	1.16843	1.43185	2.24949

8. WOOD

YEAR	PL	PK	PE	PR	PNR
1961	.48114	.95114	.98934	.68533	.76389
1962	.48371	1.04759	.99287	.70496	.77490
1963	.52047	1.11525	.98256	.72911	.83129
1964	.53984	1.17545	.98433	.77210	.82029
1965	.57044	.96548	.98093	.81705	.84397
1966	.62769	.89777	.96014	.84293	.88916
1967	.68139	.94220	.95781	.85748	.91228
1968	.74901	1.16760	.95750	.93125	.90993
1969	.82548	1.26444	.93819	1.01422	.95695
1970	.90358	.88042	.98600	.94325	.97121
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.09214	1.11230	1.02548	1.14895	1.00232
1973	1.20963	1.53587	1.10794	1.43141	1.02008
1974	1.40510	1.36828	1.24439	1.51481	1.14066
1975	1.61107	1.59861	1.42063	1.55667	1.25493
1976	1.85919	1.74424	1.75804	1.75186	1.35007

9. FURNITURE

YEAR	PL	PK	PE	PR	PNR
1961	.52782	.73307	.99294	.70550	.86726
1962	.57017	.80684	1.01576	.73292	.85988
1963	.61820	.83682	.99419	.76318	.86810
1964	.61778	.85046	1.00160	.77992	.87225
1965	.62693	.86012	.97788	.79682	.88776
1966	.68060	.97662	.93852	.81966	.90523
1967	.72967	.88852	.93494	.84649	.91037
1968	.78307	1.04668	.92364	.95767	.90437
1969	.85598	.94356	.97601	1.02177	.91823
1970	.92626	1.00537	1.00827	.87770	.97443
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.08140	1.03671	1.05218	1.22762	1.01088
1973	1.16386	1.11431	1.13942	1.54243	1.08440
1974	1.31373	1.31305	1.35032	1.49873	1.27315
1975	1.50594	1.38987	1.45459	1.46748	1.43973
1976	1.69399	1.51453	1.63696	1.65263	1.61227

10. PAPER

YEAR	PL	PK	PE	PR	PNR
1961	.53128	1.14620	.74891	.81454	.95611
1962	.54726	1.12418	.75799	.81661	.92879
1963	.56629	1.21033	.77359	.82784	.92563
1964	.58332	1.26797	.78816	.83331	.94006
1965	.61304	1.09891	.81515	.84226	.97667
1966	.67289	1.06778	.83381	.89262	1.01956
1967	.72558	.99194	.85865	.94003	1.05908
1968	.78654	.98662	.84758	.94052	1.09285
1969	.84243	1.06607	.86825	.95798	1.03726
1970	.91953	.98223	.87251	.98431	.99933
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.07404	.93986	.98800	1.00941	.99767
1973	1.16126	1.14748	1.07508	1.14319	1.07800
1974	1.36705	1.55040	1.47759	1.45247	1.39376
1975	1.61005	1.46776	1.73096	1.77019	1.65624
1976	1.86469	1.60341	2.04542	1.90284	1.79084

11. PRINTING

YEAR	PL	PK	PE	P
1961	.55422	.86570	.91934	.70910
1962	.57857	.88356	.92831	.69090
1963	.60156	.83794	.94345	.70690
1964	.62845	.91821	.94608	.80360
1965	.66025	.76620	.96318	.93750
1966	.70926	.82662	.91314	.94920
1967	.75681	.83934	.91660	.92730
1968	.81054	.83870	.92800	.91800
1969	.86646	.99869	.94710	.98110
1970	.92391	.91619	.96172	1.13950
1971	1.00000	1.00000	1.00000	1.00000
1972	1.08943	1.13608	1.02905	1.20980
1973	1.18119	1.09584	1.09775	1.55130
1974	1.35662	1.12150	1.35338	2.24560
1975	1.58143	1.25891	1.57390	2.06090
1976	1.75232	1.30850	1.70229	2.19270

12. PRIMARY

YEAR	PL	PK	PE	PNR
1961	.52877	.94405	.77918	.75821
1962	.55036	.92247	.80137	.78355
1963	.57672	.99084	.80478	.78405
1964	.59459	1.03570	.73722	.79364
1965	.62301	2.85146	.76449	.81537
1966	.66878	1.07897	.79230	.85146
1967	.72171	1.16885	.79596	.87251
1968	.77424	2.07414	.80928	.89161
1969	.82860	1.12388	.85019	.93355
1970	.91355	1.10035	.91902	1.04755
1971	1.00000	1.00000	1.00000	1.00000
1972	1.07850	.85244	1.00932	1.02991
1973	1.17690	1.00647	1.12381	1.20412
1974	1.30240	1.19723	1.33883	1.50813
1975	1.50838	1.27734	1.63190	1.63893
1976	1.69965	1.36926	1.97467	1.73980

13. METAL FABRICATING

YEAR	PL	PK	PE	PNR
1961	.51932	.69015	.83023	.83947
1962	.53944	.69551	.88436	.83689
1963	.55876	.75037	.88110	.81916
1964	.58057	.83136	.87703	.84331
1965	.60779	.88227	.87140	.86347
1966	.66779	.89983	.88044	.87931
1967	.71872	.83097	.93138	.88854
1968	.76964	.88340	.95818	.88808
1969	.84318	.91266	.94357	.92054
1970	.91480	1.00629	.94877	.97516
1971	1.00000	1.00000	1.00000	1.00000
1972	1.07330	.89839	1.03206	1.02360
1973	1.16552	1.01568	1.13595	1.12630
1974	1.30772	2.59614	1.28105	1.45545
1975	1.46493	1.44634	1.44240	1.62631
1976	1.62959	1.55642	1.77422	1.72440

14. MACHINERY

YEAR	PL	PK	PE	PNR
1961	.51130	.63385	.88276	.83067
1962	.53341	.69168	.90027	.82870
1963	.55657	.75705	.88326	.81679
1964	.57349	.84015	.86975	.83770
1965	.59229	1.05621	.88647	.86085
1966	.65404	1.13233	.88151	.87823
1967	.71178	.99833	.88369	.89038
1968	.73690	1.04494	.88705	.89299
1969	.79256	1.13935	.92834	.92243
1970	.88222	.96064	.96814	.97168
1971	1.00000	1.00000	1.00000	1.00000
1972	1.04907	1.05221	1.00664	1.01996
1973	1.08213	1.10933	1.06071	1.11842
1974	1.26601	.84261	1.18034	1.43430
1975	1.46202	1.23632	1.49666	1.64852
1976	1.61320	1.33122	1.74487	1.75351

15. TRANSPORTATION

YEAR	PL	PK	PE	PR	PNR
1961	.51376	.69616	.77883	.70653	.80447
1962	.53499	.85245	.84221	.72856	.80839
1963	.56166	.93377	.84671	.77748	.81142
1964	.58604	.86470	.84453	.78110	.83241
1965	.52156	.93762	.84653	.79622	.85175
1966	.66187	.76120	.84823	.82389	.86973
1967	.71907	.82481	.85787	.84582	.88639
1968	.77588	.93985	.86904	.98073	.89129
1969	.80564	.96710	.89154	1.02523	.92846
1970	.89144	.81153	.93144	.87123	.97897
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.04378	1.03080	1.05628	1.23590	1.02241
1973	1.10526	.99969	1.11164	1.55708	1.11498
1974	1.28414	1.02760	1.37387	1.50622	1.39975
1975	1.47446	1.28600	1.61020	1.47263	1.59521
1976	1.68246	1.39239	1.97272	1.64081	1.70336

16. ELECTRICAL PRODUCTS

YEAR	PL	PK	PE	PNR
1961	.57083	.72269	.82362	.77109
1962	.59392	.76972	.88028	.78284
1963	.61696	.82861	.87162	.78968
1964	.63268	.90902	.86662	.80577
1965	.65426	.92222	.85426	.84535
1966	.68398	.98692	.84328	.92667
1967	.73691	.88748	.84675	.93067
1968	.81327	.87375	.89775	.92863
1969	.89286	.94298	.93501	.97409
1970	.94065	.95726	.95724	1.05381
1971	1.00000	1.00000	1.00000	1.00000
1972	1.06360	1.02572	1.10483	1.00495
1973	1.13880	1.07172	1.13847	1.16741
1974	1.31984	1.09981	1.28703	1.46708
1975	1.52369	1.32853	1.56507	1.37772
1976	1.72061	1.43474	1.91681	1.48163

17. NON METALLIC

YEAR	PL	PK	PE	PNR
1961	.52755	.82917	.76142	.82942
1962	.54967	.89036	.80050	.85270
1963	.57208	.93225	.79771	.86142
1964	.58702	1.01849	.79474	.85504
1965	.60678	.95350	.80353	.86440
1966	.66247	.94607	.81129	.87499
1967	.70699	.87580	.84659	.89166
1968	.77440	.90501	.87377	.88102
1969	.85689	.95645	.91210	.91696
1970	.92869	.92782	.93438	.96372
1971	1.00000	1.00000	1.00000	1.00000
1972	1.09001	.97823	1.02578	1.01655
1973	1.19795	1.06618	1.12074	1.08795
1974	1.35735	1.19822	1.46382	1.26476
1975	1.55759	1.33388	1.87373	1.48888
1976	1.78615	1.43869	2.26013	1.63754

18. PETROLEUM

YEAR	PL	PK	PE	PR
1961	.57135	.87594	.95563	.84203
1962	.60220	.81199	.93365	.89306
1963	.62434	.80301	.92434	.90304
1964	.63169	.81272	.89774	.91695
1965	.64853	.82954	.90412	.91987
1966	.68931	.86081	.90413	.92190
1967	.74061	.85024	.92095	.92102
1968	.79911	.87837	.92617	.92183
1969	.90645	.98432	.96122	.91806
1970	.95429	.81665	.98262	.92803
1971	1.00000	1.00000	1.00000	1.00000
1972	1.12342	1.08770	1.02147	1.02575
1973	1.27266	1.40557	1.08435	1.26061
1974	1.41839	1.66765	1.29577	2.75346
1975	1.66501	1.80182	1.59921	3.40260
1976	1.89255	1.83909	2.07654	3.74029

19. CHEMICALS

YEAR	PL	PK	PE	PR	PNR
1961	.53281	.86211	.72222	.81638	.90805
1962	.54875	.88410	.75109	.80729	.90519
1963	.56564	.91444	.75916	.83655	.91501
1964	.58972	1.02602	.77669	.88459	.95242
1965	.59975	.96545	.80607	.95123	.99198
1966	.67121	.98053	.81489	.97708	.99625
1967	.71909	.95464	.82597	.90391	.97857
1968	.76940	1.02003	.84344	.85369	.93317
1969	.82922	1.01935	.83668	.94587	.89504
1970	.91126	.98358	.93853	1.01857	1.01364
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.06827	1.01614	1.09785	1.01936	1.01886
1973	1.13431	1.04510	1.16731	1.52272	1.15943
1974	1.28572	1.23460	1.43436	1.90524	1.48989
1975	1.45448	1.33535	1.89443	1.95734	1.99360
1976	1.64032	1.42500	2.36098	1.93006	1.95526

20. MISCELLANEOUS

YEAR	PL	PK	PE	PR	PNR
1961	.58625	.71646	.77653	.69165	.77899
1962	.63498	.70818	.91575	.74112	.81047
1963	.69895	.72739	.89645	.75398	.84641
1964	.71147	.78618	.91518	.77092	.86314
1965	.72548	.87152	.91716	.77838	.89001
1966	.79153	.86009	.89316	.81354	.91850
1967	.88354	.92922	.87573	.84691	.95620
1968	1.00939	.94995	.87603	.96933	1.01776
1969	1.08267	1.00274	.90137	1.01419	1.02520
1970	1.19994	.96215	.94401	.87544	1.02309
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.07666	.92781	1.03382	1.22392	1.09399
1973	1.15067	.91021	1.08324	1.52868	1.39530
1974	1.30489	.99659	1.22463	1.53701	2.02524
1975	1.46586	1.16411	1.31092	1.47713	2.21999
1976	1.63725	1.25407	1.68377	1.68084	2.08099

21. TOTAL MANUFACTURING SECTOR

YEAR	PL	PK	PE	PR	PNR
1961	.56744	.84090	.78795	.76328	.79721
1962	.58372	.86311	.79294	.79643	.82076
1963	.60698	.90721	.80706	.78908	.82229
1964	.62791	.96356	.80396	.79240	.83638
1965	.65814	.94301	.82405	.83281	.85495
1966	.70000	.92559	.83598	.88570	.88052
1967	.74419	.90673	.85341	.90131	.89351
1968	.80233	.97185	.86127	.92079	.90217
1969	.86047	1.01474	.87180	.97568	.92993
1970	.92791	.95849	.91471	.97582	.99873
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.06977	.99013	1.03324	1.12220	1.02602
1973	1.16512	1.06444	1.12233	1.42743	1.18690
1974	1.32093	1.16204	1.38929	1.59177	1.75868
1975	1.49302	1.21034	1.69048	1.70840	2.02063
1976	1.69302	1.32661	2.03136	1.73635	2.17333

Appendix 2

Table 2: Manufacturing Input Cost Shares, 1961-76

1. FOOD

YEAR	SL	SK	SE	SR	SNR
1961	.28244	.12969	.02088	.55523	.01176
1962	.27288	.12996	.02054	.56497	.01165
1963	.26930	.13471	.02062	.56321	.01217
1964	.26449	.14357	.01983	.55913	.01298
1965	.26690	.13644	.02003	.56337	.01326
1966	.26652	.13372	.01902	.56840	.01234
1967	.27295	.12989	.01858	.56421	.01437
1968	.28312	.13775	.01853	.54555	.01505
1969	.28644	.13982	.01773	.53965	.01636
1970	.29401	.13748	.01667	.53448	.01736
1971	.29927	.13694	.01700	.52953	.01725
1972	.28780	.11589	.01657	.56307	.01667
1973	.25980	.09874	.01515	.61130	.01502
1974	.26157	.09342	.01678	.61401	.01423
1975	.27375	.10287	.01765	.59025	.01548
1976	.28896	.10458	.01953	.57165	.01528

2. TOBACCO

YEAR	SL	SK	SE	SR
1961	.32205	.13241	.00671	.53883
1962	.33748	.13190	.00807	.52256
1963	.32395	.12612	.00846	.54147
1964	.33656	.13514	.00773	.52057
1965	.34414	.15417	.00852	.49316
1966	.31104	.13070	.00771	.55055
1967	.27124	.15836	.00646	.56395
1968	.31660	.12538	.00703	.55098
1969	.32317	.12576	.00720	.54386
1970	.33260	.11951	.00738	.54050
1971	.36818	.13567	.00843	.48772
1972	.38626	.13493	.00845	.47036
1973	.39528	.13169	.00878	.46425
1974	.36474	.11680	.00891	.50955
1975	.37771	.12084	.00914	.49231
1976	.36793	.11768	.00984	.50455

3. RUBBER

YEAR	SL	SK	SE	SNR
1961	.68987	.25752	.03350	.01911
1962	.70227	.24488	.03323	.01962
1963	.69479	.25331	.03305	.01885
1964	.69347	.25556	.03052	.02046
1965	.71805	.23120	.03038	.02037
1966	.70544	.24392	.02979	.02085
1967	.68108	.26673	.02875	.02344
1968	.67014	.27679	.02832	.02474
1969	.66858	.27815	.02745	.02582
1970	.74396	.20737	.03138	.01729
1971	.73057	.22277	.03080	.01586
1972	.76626	.18540	.03425	.01409
1973	.78125	.16891	.03398	.01585
1974	.72479	.22458	.03517	.01546
1975	.75082	.19751	.03845	.01322
1976	.75605	.18458	.04251	.01687

4. LEATHER

YEAR	SL	SK	SE	SR
1961	.74005	.07747	.01584	.16664
1962	.75231	.07249	.01605	.15915
1963	.78671	.07726	.01675	.11928
1964	.77805	.08536	.01617	.12042
1965	.71744	.14941	.01506	.11809
1966	.76398	.07796	.01482	.14324
1967	.79978	.08592	.01581	.09849
1968	.79090	.08923	.01519	.10468
1969	.79412	.08038	.01477	.11073
1970	.79895	.08746	.01471	.09888
1971	.78854	.09691	.01426	.10029
1972	.76056	.10000	.01416	.12528
1973	.76143	.08009	.01424	.14424
1974	.76844	.11747	.01510	.09899
1975	.79335	.10156	.01556	.08953
1976	.77376	.09421	.01618	.11585

5. TEXTILES

YEAR	SL	SK	SE	SR	SNR
1961	.59987	.33476	.03699	.02433	.00406
1962	.60348	.32915	.03556	.02744	.00437
1963	.62796	.29994	.03492	.03144	.00573
1964	.62626	.30211	.03378	.03246	.00538
1965	.64859	.28102	.03554	.02982	.00503
1966	.65487	.28157	.03431	.02493	.00432
1967	.68640	.25478	.03616	.01857	.00409
1968	.66503	.27849	.03593	.01654	.00402
1969	.67453	.26956	.03439	.01730	.00422
1970	.66308	.28662	.03228	.01315	.00487
1971	.68257	.26298	.03557	.01350	.00538
1972	.70793	.23694	.03854	.01160	.00500
1973	.71295	.23350	.03804	.01348	.00204
1974	.68196	.25703	.04302	.01551	.00248
1975	.67202	.26553	.04694	.01192	.00360
1976	.67419	.26223	.04749	.01066	.00542

6. KNITTING

YEAR	SE	SK	SE
1961	.79923	.17814	.02264
1962	.78766	.18976	.02258
1963	.79894	.17956	.02150
1964	.79584	.18359	.02057
1965	.68028	.30172	.01799
1966	.80528	.17402	.02070
1967	.80465	.17430	.02105
1968	.80372	.17598	.02030
1969	.81699	.16315	.01986
1970	.80888	.17043	.02069
1971	.80544	.17419	.02036
1972	.81801	.16009	.02190
1973	.83046	.14685	.02269
1974	.84504	.12990	.02506
1975	.83863	.13687	.02450
1976	.84772	.12654	.02574

7. CLOTHING

YEAR	SL	SK	SE	SR
1961	.85907	.06460	.00913	.06720
1962	.86300	.06260	.00892	.06548
1963	.85918	.06602	.00883	.06596
1964	.86390	.06334	.00859	.06418
1965	.86975	.05441	.00873	.06711
1966	.88413	.04738	.00885	.05963
1967	.89557	.05193	.00904	.04346
1968	.89481	.05401	.00847	.04270
1969	.89607	.05069	.00782	.04541
1970	.91163	.04782	.00761	.03294
1971	.90509	.04575	.00756	.04161
1972	.90332	.04387	.00758	.04522
1973	.89182	.03904	.00826	.06088
1974	.88444	.03925	.00853	.06778
1975	.88865	.04019	.00826	.06291
1976	.89295	.03654	.00863	.06188

8. WOOD

YEAR	SL	SK	SE	SR	SNR
1961	.39092	.11993	.02355	.46009	.00551
1962	.38550	.12565	.02496	.45821	.00568
1963	.38861	.12597	.02434	.45534	.00574
1964	.37766	.12645	.02386	.46440	.00762
1965	.39073	.10589	.02471	.47012	.00856
1966	.39924	.09796	.02425	.46986	.00869
1967	.40472	.10174	.02372	.46050	.00931
1968	.38424	.11304	.02221	.47160	.00891
1969	.37707	.11700	.02156	.47542	.00895
1970	.40670	.09577	.02217	.46615	.00921
1971	.40733	.10275	.02284	.45817	.00892
1972	.39709	.10102	.02271	.46918	.00999
1973	.36371	.11815	.02103	.48759	.00953
1974	.38668	.11303	.02345	.46559	.01125
1975	.40322	.14324	.02498	.41568	.01288
1976	.39031	.12646	.02526	.44623	.01175

9. FURNITURE

YEAR	SL	SK	SE	SR	SNR
1961	.71508	.07335	.01957	.12410	.06790
1962	.71783	.07391	.01853	.11974	.06999
1963	.72440	.07243	.01701	.11726	.06891
1964	.71542	.07328	.01705	.12264	.07160
1965	.71385	.07559	.01844	.11954	.07259
1966	.71089	.08089	.01698	.12149	.06975
1967	.72033	.07624	.01733	.11550	.07060
1968	.70639	.09046	.01732	.11382	.07202
1969	.71813	.07846	.01791	.11282	.07268
1970	.72278	.08518	.01633	.10096	.07475
1971	.72895	.08086	.01618	.09909	.07492
1972	.72140	.07331	.01581	.11786	.07162
1973	.71431	.07427	.01490	.12374	.07278
1974	.69574	.07847	.01501	.13443	.07635
1975	.72701	.08480	.01562	.10694	.06563
1976	.73107	.08644	.01690	.09949	.06610

10. PAPER

YEAR	SL	SK	SE	SR	SNR
1961	.35522	.30747	.08651	.23347	.01733
1962	.36206	.29847	.08593	.23502	.01852
1963	.35716	.31214	.08347	.22844	.01879
1964	.35198	.31333	.08379	.23130	.01959
1965	.36799	.28606	.08809	.23681	.02105
1966	.37982	.27447	.08442	.24018	.02111
1967	.39574	.26879	.08500	.23024	.02024
1968	.40375	.26631	.08359	.22534	.02102
1969	.40540	.26670	.08206	.22631	.01953
1970	.42327	.25204	.08094	.22496	.01879
1971	.42484	.25692	.08841	.21134	.01849
1972	.43926	.23894	.08752	.21406	.02023
1973	.41800	.25835	.08414	.22084	.01868
1974	.39381	.26578	.09257	.23083	.01702
1975	.41824	.26004	.09057	.21430	.01686
1976	.43637	.24132	.10563	.20085	.01583

11. PRINTING

YEAR	SL	SK	SE	SNR
1961	.76255	.21769	.01273	.00703
1962	.76054	.22015	.01274	.00657
1963	.76986	.21080	.01247	.00686
1964	.75191	.22905	.01196	.00708
1965	.78695	.19186	.01215	.00903
1966	.78669	.19389	.01183	.00759
1967	.79316	.18896	.01147	.00641
1968	.80035	.18132	.01176	.00658
1969	.78245	.20090	.01114	.00551
1970	.80033	.18468	.00997	.00501
1971	.79275	.19314	.01010	.00401
1972	.78107	.20502	.01005	.00386
1973	.80056	.18501	.01011	.00433
1974	.81458	.17024	.01071	.00447
1975	.81511	.17146	.00999	.00343
1976	.82098	.16534	.01075	.00293

12. PRIMARY

YEAR	SL	SK	SE	SNR
1961	.24680	.18028	.06546	.50745
1962	.24752	.17196	.06333	.51719
1963	.24771	.17842	.06067	.51320
1964	.24497	.17462	.05759	.52281
1965	.19217	.35580	.04390	.40814
1966	.25755	.17210	.05437	.51597
1967	.25589	.18353	.05250	.50808
1968	.22314	.27170	.04520	.45996
1969	.25723	.16507	.04998	.52772
1970	.25881	.14769	.05066	.54284
1971	.28846	.14716	.05824	.50614
1972	.30309	.12618	.05664	.51409
1973	.28092	.12791	.05482	.53635
1974	.25727	.12477	.05371	.56426
1975	.28303	.14125	.05991	.51581
1976	.28323	.14503	.05889	.51285

13. METAL FABRICATING

YEAR	SL	SK	SE	SNR
1961	.49902	.12786	.01917	.35396
1962	.50650	.11608	.01875	.35866
1963	.50060	.11601	.01820	.36519
1964	.49499	.11744	.01718	.37039
1965	.48840	.11353	.01661	.38146
1966	.50711	.11187	.01609	.36492
1967	.52564	.11026	.01637	.34772
1968	.52239	.11593	.01607	.34561
1969	.52878	.11505	.01564	.34053
1970	.52420	.12489	.01446	.33645
1971	.52080	.12107	.01447	.34367
1972	.52073	.10340	.01439	.36148
1973	.50347	.10308	.01387	.37957
1974	.41875	.19267	.01227	.37631
1975	.47910	.11596	.01406	.39088
1976	.48589	.11577	.01596	.38238

14. MACHINERY

YEAR	SL	SK	SE	SNR
1961	.65514	.14692	.01645	.18149
1962	.65498	.14662	.01512	.18329
1963	.64997	.14703	.01372	.18928
1964	.62565	.15114	.01300	.21021
1965	.60624	.17399	.01211	.20767
1966	.61335	.17350	.01188	.20127
1967	.65375	.15436	.01191	.17998
1968	.65158	.16891	.01204	.16746
1969	.64652	.16894	.01174	.17281
1970	.68256	.14551	.01158	.16034
1971	.66246	.16117	.01296	.16342
1972	.66239	.15350	.01375	.17036
1973	.64070	.14624	.01344	.19962
1974	.65177	.09488	.01328	.24007
1975	.62376	.12072	.01252	.24301
1976	.63299	.12952	.01480	.22268

15. TRANSPORTATION

YEAR	SL	SK	SE	SR	SNR
1961	.60330	.22334	.01943	.00379	.15014
1962	.57815	.23567	.01804	.00383	.16431
1963	.57653	.23211	.01684	.00358	.17094
1964	.58953	.20522	.01582	.00376	.18568
1965	.57996	.20985	.01564	.00498	.18957
1966	.59925	.17579	.01617	.00540	.20338
1967	.59675	.19264	.01630	.00453	.18978
1968	.58827	.20806	.01624	.00524	.18218
1969	.57970	.20265	.01594	.00701	.19470
1970	.60012	.18539	.01616	.00748	.19086
1971	.57966	.20308	.01589	.01017	.19121
1972	.57421	.18989	.01607	.01265	.20719
1973	.58246	.16439	.01595	.01379	.22341
1974	.58805	.15549	.01683	.01663	.22300
1975	.57306	.18401	.01776	.01123	.21394
1976	.59272	.17978	.01948	.00846	.19956

16. ELECTRICAL PRODUCTS

YEAR	SL	SK	SE	SNR
1961	.65639	.12128	.01640	.20593
1962	.65964	.11914	.01580	.20542
1963	.65453	.12105	.01568	.20874
1964	.64126	.12499	.01460	.21915
1965	.62933	.11796	.01400	.23870
1966	.62074	.11675	.01264	.24986
1967	.64380	.11038	.01331	.23251
1968	.65220	.10925	.01322	.22533
1969	.64615	.10949	.01252	.23183
1970	.63659	.11281	.01219	.23841
1971	.64940	.11717	.01235	.22108
1972	.63905	.11736	.01269	.23090
1973	.62415	.11083	.01214	.25288
1974	.60672	.10182	.01188	.27958
1975	.63279	.11639	.01308	.23774
1976	.63718	.11887	.01452	.22943

17. NON METALLIC

YEAR	SL	SK	SE	SNR
1961	.46222	.27713	.09404	.16661
1962	.46133	.27668	.09320	.16879
1963	.45674	.28248	.08979	.17098
1964	.44801	.28962	.08566	.17670
1965	.45764	.26783	.08907	.18546
1966	.46854	.26996	.08893	.17256
1967	.48102	.27077	.08537	.16284
1968	.48436	.26854	.08210	.16500
1969	.49131	.26871	.07899	.16098
1970	.49390	.27052	.08010	.15548
1971	.49530	.27063	.08097	.15309
1972	.51959	.25084	.08597	.14360
1973	.51035	.24800	.08669	.15496
1974	.49800	.24446	.09970	.15784
1975	.49040	.24757	.10097	.16107
1976	.48512	.24438	.10976	.16074

18. PETROLEUM

YEAR	SL	SK	SE	SNR
1961	.11907	.16846	.01098	.70149
1962	.12003	.14947	.01000	.72049
1963	.11071	.13997	.00977	.73954
1964	.10670	.13676	.01058	.74596
1965	.10224	.13520	.01040	.75217
1966	.11329	.13190	.01025	.74455
1967	.12219	.13189	.01054	.73537
1968	.12134	.13120	.01179	.73567
1969	.12719	.12791	.01246	.73244
1970	.12884	.12477	.01231	.73408
1971	.11267	.13473	.01117	.74143
1972	.11136	.14033	.01118	.73713
1973	.09692	.14731	.00978	.74599
1974	.05856	.09611	.00637	.83896
1975	.05564	.09209	.00709	.84518
1976	.05590	.09277	.00873	.84259

19. CHEMICALS

YEAR	SL	SK	SE	SR	SNR
1961	.49031	.36515	.07358	.01417	.05680
1962	.48301	.37061	.07171	.01522	.05946
1963	.48113	.37116	.07171	.01573	.06027
1964	.46646	.39027	.06667	.01514	.06146
1965	.47974	.37111	.06837	.01564	.06514
1966	.47358	.37487	.07001	.01478	.06676
1967	.48410	.37300	.06823	.01346	.06121
1968	.47928	.38344	.06472	.01327	.05928
1969	.48983	.37239	.06500	.01358	.05920
1970	.51017	.35202	.06621	.01349	.05811
1971	.51762	.34727	.06652	.01326	.05533
1972	.51110	.34518	.06718	.01424	.06231
1973	.50798	.32993	.07363	.01768	.07077
1974	.48467	.34128	.07866	.01834	.07704
1975	.46817	.35291	.07759	.01603	.08529
1976	.45173	.37103	.09879	.01295	.06550

20. MISCELLANEOUS

YEAR	SL	SK	SE	SR	SNR
1961	.72822	.08055	.01861	.02111	.15151
1962	.72698	.07588	.01675	.02045	.15994
1963	.72930	.07442	.01590	.02024	.16014
1964	.73003	.08049	.01588	.01950	.15410
1965	.71719	.08906	.01645	.01979	.15751
1966	.73013	.08745	.01665	.01560	.15017
1967	.70963	.09208	.01660	.02317	.15852
1968	.71995	.09088	.01641	.02086	.15190
1969	.72728	.09169	.01685	.02118	.14300
1970	.73368	.08939	.01784	.02290	.13618
1971	.68688	.10677	.01387	.02933	.16314
1972	.70102	.09366	.01486	.02353	.16693
1973	.67952	.08122	.01419	.02121	.20386
1974	.65484	.07418	.01186	.01929	.23983
1975	.67503	.08043	.01282	.02079	.21094
1976	.70909	.07961	.01306	.01458	.18367

21. TOTAL MANUFACTURING SECTOR

YEAR	SL	SK	SE	SR	SNR
1961	.39018	.19344	.04009	.19044	.18585
1962	.38934	.18995	.03873	.19115	.19082
1963	.38856	.19259	.03777	.18541	.19567
1964	.38598	.19416	.03705	.18289	.19992
1965	.39243	.18584	.03706	.17847	.20620
1966	.39902	.17998	.03615	.18110	.20375
1967	.40521	.18022	.03592	.18060	.19805
1968	.40343	.18798	.03514	.17402	.19943
1969	.40614	.18783	.03434	.17413	.19757
1970	.40935	.17963	.03431	.17006	.20666
1971	.41079	.18496	.03589	.16776	.20060
1972	.41303	.17233	.03499	.17903	.20062
1973	.39519	.16201	.03333	.19507	.21440
1974	.36699	.14936	.03545	.18138	.26682
1975	.37315	.15203	.03617	.17313	.26552
1976	.38063	.15529	.04065	.17084	.25259

Appendix 2

Table 3: Percentage Share of Value of Shipments by Province and by Industry

TABLE 3

% SHARE OF VALUE OF SHIPMENTS
BY PROVINCES AND BY INDUSTRY (1975)

		NFD	PEI	NS	NBW	MAN	SASK	ALTA	B.C.	QUE	ONT
1.	Food	47.17257	92.87816	30.83045	39.10476	36.63838	44.71039	35.95292	17.82925	18.58807	14.12805
2.	Tobacco	0	0	0	0	0	0	0	0	1.38698	0.90303
3.	Rubber	0	0	0	0	0	0	1.28929	0.52021	1.83593	3.0404
4.	Leather	0	0	0	0	0.74148	0	0.18257	0.05065	1.03329	0.64511
5.	Textiles	0	0	1.6018	0.11697	0.72708	0	0.69271	0.56377	4.89296	2.16235
6.	Knitting	0	0	1.25016	0	0.46521	0.53335	0	0	1.59464	0.30885
7.	Clothing	0	0	0.14213	0	5.77362	1.66523	1.00313	0.60503	6.01433	1.01884
8.	Wood	2.48412	0	3.5278	7.92525	2.52101	6.17389	5.51563	23.73801	3.10438	1.26603
9.	Furniture	0.21285	0	0.60693	0.80445	2.20839	0.23698	1.06749	0.8286	1.88257	1.3468
10.	Paper	30.81511	0	12.42577	31.92097	5.52414	0	3.60533	19.7472	9.37937	4.29404
11.	Printing	2.46275	3.84106	2.05567	1.65107	3.96845	4.04523	2.74996	2.72667	3.32194	2.86032
12.	Primary	0	0	0	0	7.42076	0	6.80745	4.93863	8.47722	7.53245
13.	Metal Fab.	3.55637	0	3.3283	4.84924	8.17287	6.22771	6.46776	5.63589	6.11999	7.40604
14.	Machinery	0	3.05235	0	0	8.91859	6.24245	3.14725	2.62695	2.78258	5.77983
15.	Transport	3.18204	0	14.48703	4.49104	6.7868	2.09836	4.22187	4.54566	6.26982	24.09678
16.	Electrical Products	0	0	1.72728	1.76569	2.87563	2.41305	1.63974	1.72796	5.14165	7.54092
17.	Non-metallic	4.67855	0.22843	2.04338	3.01178	2.91794	5.28796	4.73552	2.74832	2.90921	2.57589
18.	Petroleum & Coal Products	0	0	24.16621	3.25268	0	17.74677	13.97059	7.16096	6.65569	3.30207
19.	Chemicals	5.43564	0	1.37034	0	3.28736	1.8364	6.15918	3.29795	6.63158	6.73635
20.	Miscellaneous	0	0	0.43404	1.1061	1.05237	0.78223	0.79159	0.7083	1.9778	3.05586

Source: Statistics Canada SC(31-203)

Appendix 3. Estimated Regression Results

APPENDIX 3: ESTIMATED REGRESSION RESULTS

	1. FOOD	2. TOBACCO	3. RUBBER
AL	1.00306	1.60903	.78036
	(6.146)	(6.824)	(25.511)
AK	.05172	.03554	.17930
	(.695)	(.283)	(6.269)
AE	.07445	-.00238	.03648
	(5.859)	(-.239)	(12.201)
AR	-.14000	-.64219	0.00386
	(-.901)	(-1.675)	(0.542)
ANR	.01076	--	--
	(.344)	--	--
BLL	.12071	.17213	.10912
	(8.023)	(8.944)	(4.968)
BLK	.00394	-.01930	-.09707
	(.706)	(-1.899)	(-4.729)
BLE	-.00070	(.00055)	0.00170
	(-.659)	(.652)	(.723)
BLR	-.13537	(-.15338)	-.01374
	(-9.147)	(-4.890)	(-2.722)
BLNR	.01142	--	--
	(4.351)	--	--
BKK	.07474	.10176	.10808
	(19.742)	(6.229)	(5.558)
BKE	.000718	(-.00201)	-.01718
	(1.408)	(-1.942)	(-6.432)
BKR	-.08203	-.08045	.00618
	(-13.470)	(-3.211)	(.993)
BKNR	.00263	--	--
	(1.794)	--	--
BEE	.01504	.00528	.03102
	(21.575)	(7.168)	(6.489)
BER	-.00535	-.00382	-.01554
	(-6.756)	(-2.365)	(-2.165)

	1. FOOD	2. TOBACCO	3. RUBBER
BENR	-.00971	--	--
	(-6.745)	--	--
BRR	.23085	.23764	.02310
	(13.680)	(4.708)	(1.806)
BRNR	-.00810	--	--
	(-5.418)	--	--
BNNR	.00376	--	--
	(.692)	--	--
DLQ	-.07960	-.20927	-.02424
	(-4.345)	(-5.301)	(-1.443)
DKQ	.00940	.01609	.02049
	(1.119)	(.766)	(1.304)
DEQ	-.00648	.00175	-.00285
	(-4.535)	(1.050)	(-1.985)
DRQ	.07589	.19143	.0066
	(4.347)	--	--
DNRQ	.00079	--	--
R^2(L)	.8472	.8913	.8744
D.W.(L)	.7581	1.6967	1.3173
R^2(K)	.9762	.7547	.8862
D.W.(K)	1.4572	1.7939	1.4298
R^2(E)	.9801	.8070	.9489
D.W.(E)	2.2690	2.4287	2.5691
R_2(R)	.9428	--	--
D.W.(R)	.8249	--	--

1. These estimates are from the TSP program (version 3.5, 1981) while results in the text are obtained from a written IZE program. The two estimates are quite close and probably only differ because of the stronger convergence criteria imposed in the written program.

2. t-statistics appear in the parentheses.

APPENDIX 3: ESTIMATED REGRESSION RESULTS

	4. LEATHER	5. TEXTILE	6. KNITTING
AL	0.96091	.68761	1.02909
	(1.440)	(175.309)	(11.573)
AK	-0.82856	.25955	-.06817
	(-1.521)	(61.031)	-.820
AE	-.01037	.03563	.03909
	(-.38883)	(67.801)	(3.916)
AR	.87802	.01250	--
	(1.105)	(12.347)	--
ANR	--	.00470	--
	--	(10.042)	--
BLL	.10812	.12045	.11603
	(3.556)	(10.048)	(7.745)
BLK	-.04758	-.08433	-.12268
	(-3.098)	(-6.549)	-8.769
BLE	-.00211	-.00305	.00665
	(-1.717)	(-1.510)	(3.518)
BLR	-.05842	-.02839	--
	(-2.040)	(-9.023)	--
BLNR	--	-.00467	--
	--	(-2.680)	--
BKK	.05230	.08960	.12934
	(3.592)	(6.247)	(9.855)
BKE	-.00132	-.02403	-.00666
	(-2.107)	(-13.122)	-5.686
BKR	-.00396	.01815	--
	(-.204)	(4.978)	--
BKNR	--	.00061	--
	--	(.357)	--
BEE	.00442	.02133	.0000097
	(5.248)	(4.125)	(.00633)
BER	-.00100	.00658	--
	(-.943)	(2.095)	--

	4. LEATHER	5. TEXTILE	6. KNITTING
BENR	--	-.00082	--
		(-.282)	
BRR	.06281	.01024	--
	(2.094)	(3.216)	
BRNR	--	-.00658	--
	--	(-3.079)	
BNNR	--	.01147	--
	--	(3.382)	
DLQ	-.03111	--	-.04260
	(-.256)	--	(-2.474)
DKQ	0.16763	--	.04591
	(1.686)	--	(2.850)
DEQ	.00456	--	-.00331
	(.941)	--	
DRQ	-.14108	--	--
	--	--	--
DNRQ	--	--	--
	1.4056	.889	
R^2(L)	.4994	.7904	.9010
D.W.(L)	1.4056	.899	1.3515
R^2(K)	1.3747	.8465	.9196
R^2(K)	.4994	.7904	1.3615
R^2(E)	.5821	.9138	--
D.W.(E)	1.6697	1.1696	--
R^2(R)	--	.8707	--
D.W.(R)	--	.8412	--

APPENDIX 3: ESTIMATED REGRESSION RESULTS

	7. CLOTHING	8. WOOD	9. FURNITURE
AL	1.21315	.96428	.72481
	(7.190)	(10.097)	(207.708)
AK	.13714	-.47356	.08273
	(1.809)	(-2.335)	(49.795)
AE	-.00131	-.01294	.16210
	(-.081)	(-.658)	(48.528)
AR	-.34898	.32056	.10567
	(-2.280)	(1.422)	(37.767)
ANR	--	.20166	.07057
	--	(3.175)	(50.661)
BLL	.09874	.08775	.04525
	(5.604)	(4.895)	(2.489)
BLK	-.02915	-.03305	.02442
	(-4.046)	(-2.416)	(2.844)
BLE	-.00175	-.00207	-.00543
	(- 1.290)	(-.720)	(-2.397)
BLR	-.06784	-.07777	-.06634
	(-4.165)	(-2.360)	(-4.312)
BLNR	--	.02514	.00210
	--	(3.770)	(.273)
BKK	.02618	.06768	.00826
	(4.239)	(2.402)	(.621)
BKE	-.00147	-.00116	-.00721
	(-1.164)	(-.447	(-2.630)
BKR	.00445	-.03827	-.02824
	(1.158)	(-1.099)	(-2.684)
BKNR	--	.00481	.00277
	--	(.742)	(.227)
BEE	.00220	.00788	-.00227
	(1.577)	6.506	(-452)

	7. CLOTHING	8. WOOD	9. FURNITURE
BER	.00103	-.00268	.00035
	(1.083)	(-.465)	(.140)
BENR	--	-.00197	.01455
	--	(-1.022)	(1.830)
BRR	.06236	.12109	.08673
	(4.271)	(1.748)	(4.614)
BRNR	--	-.00237	.00750
	--	(-.184)	(.854)
BNNR	--	-.02561	-.02692
	--	(-4.200)	(-1.733)
DLQ	-.04618	-.07317	--
	(-1.837)	(-5.876)	--
DKQ	-.01376	.07605	--
	(-1.207)	(2.871)	--
DEQ	.00139	.00473	--
	(.570)	(1.833)	--
DRQ	.05855	.01759	--
	--	(.596)	--
DNRQ	--	-.0252	--
R^2L	.8138	.8172	.2147
D.W.L.	1.4302	.9640	2.3477
R^2K	.9679	.3080	.5281
D.W.K.	1.0121	1.1492	1.8619
R^2E	.5503	.5656	.6818
D.W.E.	1.3564	1.4193	1.1671
R^2R	--	.4597	.6103
D.W.R.	--	1.2809	2.3631

APPENDIX 3: ESTIMATED REGRESSION RESULTS

	10. PAPER	11. PRINTING	12. PRIMARY
AL	.90882	1.29731	.86881
	(11.038)	(12.871)	(6.245)
AK	.15791	-.33821	.41674
	(1.248)	(-3.077)	(2.465)
AE	.10505	.01054	.27176
	(2.279)	(.653)	(4.093)
AR	-.17488	.03036	-.55730
	(-1.585)	(.967)	(-2.144)
ANR	.00310	--	--
	(.131)	--	--
BLL	.16442	.16468	.17677
	(17.035)	(10.128)	(8.437)
BLK	-.07414	-.15273	-.02566
	(-10.267)	(-9.968)	(-2.466)
BLE	-.01559	-.00579	-.00105
	(-2.544)	(-2.213)	(-.141)
BLR	-.08033	-.00616	-.15006
	(-5.087)	(-1.061)	(-4.329)
BLNR	.00564	--	--
	(1.620)	--	--
BKK	.06963	.15078	.05878
	(5.790)	(8.899)	(3.627)
BKE	-.01465	.00072	-.01430
	(-3.451)	(.433)	(-3.353)
BKR	.01908	.00123	-.01882
	(1.642)	(.256)	(-.757)
BKNR	.000074	--	--
	(0.032)	--	--
BEE	.10135	.00403	.02333
	(14.468)	(2.301)	(2.643)

	10. PAPER	11. PRINTING	12. PRIMARY
BER	-.06783	.00104	-.00798
	(-5.592)	(1.025)	(-.577)
BENR	-.00327	--	--
	(-.838)	--	--
BRR	.15300	.00390	.17686
	(4.970)	(1.567)	(3.095)
BRNR	-.02391	--	--
	(-3.104)	--	--
BNNR	.02148	--	--
	(6.114)	--	--
DLQ	-.06054	-.07133	-.06558
	(-5.905)	(-4.955)	(-4.202)
DKQ	.01185	.07511	-.03054
	(.748)	(4.763)	(-1.591)
DEQ	-.00177	-.000047	-.02439
	(-.309)	(-.02042)	(-3.257)
DRQ	.04849	-.00373	-.12051
	(3.537)	--	--
DNRQ	.00197	--	--
R^2L	.8579	.9654	.9431
DW	1.9704	.9390	1.9555
R^2K	.9251	.9405	.8904
DW	1.6462	.8342	1.1846
R^2E	.9049	.8951	.8976
DW	1.7424	1.5529	2.0197
R^2R	.8034	--	--
DW	1.1694	--	--

APPENDIX 3 ESTIMATED REGRESSION RESULTS

	13. METAL FABRICATING	14. MACHINERY	15. TRANSPORT
AL	1.16765	1.17286	.57833
	(5.534)	(6.135)	(143.176)
AK	.37188	.32626	.19374
	(3.367)	(6.490)	(39.355)
AE	.02335	.03547	.01548
	(3.045)	(3.313)	(37.920)
AR	-.56287	-.53458	.00831
	(-2.279)	(-2.616)	(7.135)
ANR	--	--	.20415
	--	--	(25.611)
BLL	.13038	.13863	-.02699
	(3.388)	(3.146)	(-1.772)
BLK	.02561	.00537	-.04751
	(1.318)	(.491)	(-3.151)
BLE	-.00577	.00225	-.00454
	(-4.414)	(1.254)	(-3.391)
BLR	-.15022	-.14625	.00801
	(-3.436)	(-3.077)	(1.814)
BLNR	--	--	.07102
	--	--	(2.660)
BKK	.03991	.08540	.10420
	(1.796)	(15.275)	(3.901)
BKE	-.00412	-.00507	-.00648
	(-2.704)	(-5.113)	(-3.126)
BKR	-.06140	-.08571	-.01445
	(-1.799)	(-6.644)	(-3.139)
BKNR	--	--	-.03577
	--	--	(-.924)
BEE	.01261	.00461	.01233
	(8.197)	(.922)	(9.189)

	13. METAL FABRICATING	14. MACHINERY	15. TRANSPORT
BER	-.00272	-.00179	.00264
	(-.969)	(-.343)	(2.739)
BENR	--	--	-.00395
	--	--	(-1.169)
BRR	.21434	.23375	.01149
	(3.484)	(4.846)	(2.809)
BRNR	--	--	-.00769
	--	--	(-1.003)
BNNR	--	--	-.02362
	--	--	(-.422)
DLQ	-.08089	-.07011	--
	(-3.095)	(-2.713)	--
DKQ	-.03181	-.02426	--
	(-2.326)	(-3.555)	--
DEQ	-.00112	-.00310	--
	(-1.188)	(-2.107)	--
DRQ	.11382	.09747	--
	--	--	--
DNRQ	--	--	--
R^2L	.5693	.3898	.3477
D.W.L	.6611	1.9586	1.6909
R^2K	.2589	.9532	.7414
D.W.K	.8267	1.9385	.6692
R^2E	.9531	.7905	.5206
D.W.E	.9384	1.7579	.7469
R^2R	--	--	.7694
D.W.R	--	--	1.5519

APPENDIX 3: ESTIMATED REGRESSION RESULTS

	16. ELECTRICAL PRODUCTS	17. NON-METALLIC	18. PETROLEUM. & COAL PRODUCTS
AL	1.17146	.80406	.52832
	(9.882)	(6.003)	(10.761)
AK	.27899	.51398	.23047
	(8.003)	(4.450)	(3.426)
AE	.02657	-.05450	-.00778
	(5.115)	(-.858)	(-.179)
AR	-.47702	-.26354	.24900
	(-4.396)	(-1.775)	(3.215)
ANR	--	--	--
	--	--	--
BLL	.09370	.15383	.06435
	(3.380)	(9.365)	(6.284)
BLK	.02955	-.00182	-.04167
	(3.729)	(-.133)	(-2.948)
BLE	-.00522	-.05291	.00190
	(-3.853)	(-6.607)	(.436)
BLR	-.11803	-.09909	-.02458
	(-4.626)	(-4.624)	(-2.191)
BLNR	--	--	--
	--	--	--
BKK	.02925	.03493	.11664
	(5.389)	(2.012)	(4.340)
BKE	-.00371	-.02841	-.00343
	(-5.068)	(-2.925)	(-1.466)
BKR	-.05510	-.00470	-.07155
	(-6.468)	(-.152)	(-3.624)
BKNR	--	--	--
	--	--	--
BEE	.01186	.07643	.00991
	(10.308)	(9.072)	(1.062)

	16. ELECTRICAL PRODUCTS	17. NON-METALLIC	18. PETROLEUM AND COAL PRODUCTS
BER	-.00293	.00489	-.00837
	(-2.773)	(.246)	(-1.504)
BENR	--	--	--
	--	--	--
BRR	.17606	.09890	.10450
	(8.035)	(1.598)	(5.745)
BRNR	--	--	--
	--	--	--
BNNR	--	--	--
	--	--	--
DLQ	-.06385	-.04308	-.05470
	(-4.488)	(-2.268)	(-8.344)
DKQ	-.01956	-.03586	-.01294
	(-4.666)	(-2.187)	(-1.438)
DEQ	-.00172	.01951	.00255
	(-2.793)	(2.163)	(.442)
DRQ	.08513	.05943	.06509
	--	--	--
DNRQ	--	--	--
	--	--	--
R^2L	.6767	.9197	.9228
DW	.8425	1.553	.9856
R^2K	.8425	.8691	.8268
DW	1.2746	1.7143	1.344
R^2E	.9784	.8957	.8751
DW	2.6392	1.3450	1.4351

APPENDIX 3: ESTIMATED REGRESSION RESULTS

	19. CHEMICALS	20. MISCELLANEOUS	21. TOTAL
AL	.50064	.71985	.59201
	(95.474)	(111.407)	(4.801)
AK	.35496	.09374	.50298
	(83.897)	(37.762)	(6.283)
AE	.06605	.01647	.08569
	(86.520)	(31.318)	(3.484)
AR	.01342	.02262	.51752
	(81.531)	(18.694)	(6.139)
ANR	.06494	.14732	-.69819
	(21.131)	(29.503)	(-7.862)
BLL	.05862	.02149	.11207
	(3.578)	(.473)	(5.754)
BLK	-.03516	.03296	.03121
	(-2.723)	(1.759)	(3.246)
BLE	-.01948	-.00364	-.00560
	(-2.433)	(-.933)	(-1.638)
BLR	-.01402	.00448	-.04401
	(-9.688)	(.530)	(-3.472)
BLNR	.01003	-.05529	-.09366
	(.860)	(-1.724)	(-7.332)
BKK	.10383	.00645	.05209
	(7.465)	(.533)	(6.435)
BKE	-.02138	.01092	-.00769
	(-4.340)	(3.979)	(-3.651)
BKR	.00111	.00689	-.04903
	(1.139)	(1.492)	(-5.979)
BKNR	-.04841	-.05721	-.02658
	(-3.725)	(-4.758)	(-3.626)
BEE	.01851	-.00863	.02025
	(1.073)	(-4.139)	(4.840)

	19. CHEMICALS	20. MISCELLANEOUS	21. TOTAL
BER	.01964	.00246	-.00491
	(6.727)	(1.265)	(-1.554)
BENR	.00270	-.00111	-.00204
	(.164)	(-.368)	(-.498)
BRR	.01438	-.00511	.13346
	(13.890)	(-.976)	(8.979)
BRNR	-.02110	-.00871	-.03550
	(-6.778)	(-1.284)	(-3.284)
BNNR	.05678	.12232	.15778
	(2.774)	(5.479)	(12.820)
DLQ	--	--	-.01692
	--	--	(-1.445)
DKQ	--	--	-.3054
	--	--	(-4.020)
DEQ	--	--	-.00477
	--	--	(-2.043)
DRQ	--	--	-.03330
	--	--	(-4.171)
DNRQ	--	--	.08553
R^2L	.4170	.4730	.9051
DW	.7856	.9291	1.4746
R^2K	.6675	.4407	.9818
DW	1.0773	1.3884	2.0588
R^2E	.8799	.4045	.9245
DW	1.5347	1.2902	2.8574
R^2R	.9638	.1034	.8877
DW	1.9404	1.2117	2.0494

Appendix 4. Miscellaneous Data and Regression Results

Table 1: Factor Intensity

1. FOOD

YEAR	L	K	E	R	NR
1961	1.42454	.93067	1.11389	1.05424	.65417
1962	1.35854	.93013	1.07069	1.03175	.64902
1963	1.34246	.96600	1.10179	1.08335	.69975
1964	1.28277	.93198	1.04843	1.08627	.74375
1965	1.24397	.91717	1.06378	1.04043	.76634
1966	1.21115	.91863	1.06274	1.03615	.73606
1967	1.15894	.91919	1.04048	1.03290	.84715
1968	1.14207	.94702	1.05271	1.01565	.89226
1969	1.08237	.96365	1.06077	.99951	.99743
1970	1.05632	.98873	1.01873	1.00340	1.02399
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	.94632	.98572	.97839	.99358	.97784
1973	.94023	1.00810	.97365	.97420	.99447
1974	.96767	1.07779	1.04755	1.04055	.97337
1975	.96070	1.10151	1.02971	1.06084	1.03162
1976	.91689	1.06637	.95882	1.07792	.95411

2. TOBACCO

YEAR	L	K	E	R
1961	1.47458	.95073	.75126	1.05006
1962	1.56656	.98634	.86575	1.06539
1963	1.38669	.93867	.87031	1.02779
1964	1.37050	.97599	.78005	1.16113
1965	1.30679	.98072	.83526	.96314
1966	1.17331	.92447	.81342	.96613
1967	1.11813	.90002	.83652	1.04762
1968	1.16777	1.03831	.89991	1.11210
1969	1.05105	.98795	.94333	1.05177
1970	1.01708	.96527	.97401	1.13627
1971	1.00000	1.00000	1.00000	1.00000
1972	.94832	.97699	.94727	.92654
1973	.93637	.99030	.96308	.90307
1974	.82762	.89931	.91203	1.00212
1975	.84687	.93111	.92636	.97465
1976	.75893	.89102	.85175	1.03499

3. RUBBER

YEAR	L	K	E	NR
1961	2.30456	1.66448	1.47585	1.45758
1962	2.01474	1.40871	1.20806	1.31459
1963	1.97300	1.34714	1.22727	1.23171
1964	1.91336	1.25133	1.13607	1.34972
1965	1.82483	1.20646	1.10203	1.24937
1966	1.78539	1.18562	1.07501	1.30484
1967	1.73744	1.22886	1.04463	1.44400
1968	1.85774	1.33586	1.05109	1.59239
1969	1.78813	1.39456	1.04815	1.67540
1970	1.07046	.95506	1.04369	1.05992
1971	1.00000	1.00000	1.00000	1.00000
1972	.94690	.96710	1.04643	.84735
1973	.90789	.92408	.99952	.88143
1974	.91286	1.02384	.97554	.85854
1975	.95523	1.18082	1.11320	.76696
1976	.88810	1.06885	1.00738	.97325

4. LEATHER

YEAR	L	K	E	R
1961	1.34574	.92398	.91950	1.68099
1962	1.32298	.91828	.87244	1.53001
1963	1.29035	.92237	.89639	1.18420
1964	1.20082	.88547	.84847	1.23836
1965	1.19223	.88747	.88354	1.30174
1966	1.18936	.90975	.93252	1.34529
1967	1.18873	.96453	.99548	.98390
1968	1.12365	.91531	.97037	1.04890
1969	1.09511	.95705	.98196	1.07896
1970	1.06129	1.04474	.98409	.94380
1971	1.00000	1.00000	1.00000	1.00000
1972	1.03174	.69430	1.02010	.76596
1973	1.01282	1.14531	.93499	.78458
1974	.98514	1.15186	.95777	.81245
1975	.95796	1.15086	1.03001	.93941
1976	.89503	1.07679	1.00359	.91091

5. TEXTILES

YEAR	L	K	E	R	NR
1961	1.73281	1.36248	1.25133	1.91628	.96396
1962	1.61376	1.22180	1.16133	2.07324	1.06635
1963	1.54472	1.12002	1.09084	2.12436	1.27352
1964	1.49252	1.06930	1.05405	2.14973	1.22672
1965	1.47695	1.11172	1.09047	2.12114	1.07568
1966	1.45352	1.15889	1.07590	1.84708	.95844
1967	1.38020	1.16248	1.11512	1.47887	.87083
1968	1.20415	1.09517	1.08222	1.31492	.89156
1969	1.08007	.98053	.95326	1.29377	.85812
1970	1.09924	1.07176	1.05757	1.02387	.98982
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	.90452	.87103	.95440	.81449	.84004
1973	.87915	.84325	.90829	.74261	.33169
1974	.89856	.91392	.88842	.74100	.38589
1975	.88113	1.01700	.96659	.53695	.52323
1976	.83806	1.01532	.89923	.52571	.77240

6. KNITTING

YEAR	L	K	E
1961	1.96904	1.58126	1.16588
1962	1.92878	1.56862	1.23862
1963	1.82665	1.48243	1.18284
1964	1.69335	1.34044	1.06241
1965	1.59564	1.23887	1.07103
1966	1.44938	1.15468	1.04116
1967	1.42763	1.18890	1.16022
1968	1.26194	1.02162	1.04894
1969	1.20262	1.01023	1.05056
1970	1.13504	1.07871	1.09087
1971	1.00000	1.00000	1.00000
1972	.91118	.96093	1.03548
1973	.88169	.95812	1.01730
1974	.90086	1.02316	1.11310
1975	.82051	.96976	1.57438
1976	.78366	.96547	.98090

7. CLOTHING

YEAR	L	K	E	R
1961	1.39844	1.35508	.89809	1.21753
1962	1.33462	1.28914	.90907	1.17815
1963	1.29412	1.23590	.88374	1.17751
1964	1.25726	1.17045	.86082	1.17702
1965	1.21693	1.12910	.90343	1.14251
1966	1.13439	1.07316	.98883	1.16945
1967	1.14197	1.08801	1.03076	.96348
1968	1.09503	1.04745	1.00379	.91017
1969	1.07121	1.02606	.98417	.99202
1970	1.07666	1.06119	.98890	.82786
1971	1.00000	1.00000	1.00000	1.00000
1972	.93949	.94587	1.04147	.82514
1973	.89433	.95296	1.17656	.97434
1974	.90527	1.02587	1.53452	1.35877
1975	.89494	1.05269	1.20098	1.18400
1976	.86032	1.03038	1.20313	.99663

8. WOOD

YEAR	L	K	E	R	NR
1961	1.40667	.86543	.73494	1.03333	.57055
1962	1.37422	.81990	.77316	.99640	.57755
1963	1.32023	.79179	.78114	.98174	.55747
1964	1.26163	.76912	.77973	.96433	.76547
1965	1.24864	.79257	.81898	.93250	.84447
1966	1.20444	.81917	.85290	.93841	.84525
1967	1.17079	.84379	.87060	.94112	.91948
1968	1.09160	.81666	.88020	.95799	.95227
1969	1.07922	.86671	.96821	.98459	1.00934
1970	1.02843	.98529	.91638	1.00388	.98974
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	1.00872	.99893	1.09590	1.00719	1.26284
1973	.99412	1.00829	1.11902	1.00126	1.41181
1974	.99183	1.18033	1.21137	.98482	1.62441
1975	.97563	1.38473	1.22233	.92543	1.82858
1976	.87232	1.19426	1.06453	.94096	1.65233

9. FURNITURE

YEAR	L	K	E	R	NR
1961	1.41108	.93948	.92479	1.34775	.79347
1962	1.40826	.92371	.91941	1.34431	.88585
1963	1.35594	.90291	.89194	1.30788	.89373
1964	1.31906	.88479	.87388	1.31758	.90974
1965	1.24958	.86944	.93225	1.21107	.87307
1966	1.17387	.83913	.91621	1.22544	.84260
1967	1.14435	.89663	.96826	1.16356	.87470
1968	1.09859	.94880	1.02894	1.06472	.94360
1969	1.03797	.92745	1.02301	1.00494	.95278
1970	1.02991	1.00810	.96344	1.11682	.98515
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	.92841	.88713	.94220	.98290	.95938
1973	.90707	.88801	.87104	.87225	.96509
1974	.96387	.98051	.91171	1.20093	1.06201
1975	1.00060	1.13999	1.00303	1.11104	.91930
1976	.97444	1.16175	1.05063	.99994	.90067

10. PAPER

YEAR	L	K	E	R	NR
1961	1.21380	.80528	1.00775	1.04602	.75629
1962	1.20649	.80064	.99350	1.05507	.83539
1963	1.18227	.79943	.97199	1.03984	.87421
1964	1.14413	.77480	.96869	1.05795	.90803
1965	1.12673	.80798	.97473	1.06089	.92953
1966	1.11078	.83645	.95740	1.06440	.93604
1967	1.15621	.94989	1.00842	1.04374	.93078
1968	1.11514	.96962	1.02953	1.04628	.95996
1969	1.04916	.90191	.99018	1.03535	.94327
1970	1.02859	.94815	.99614	1.02664	.96556
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	.94669	.97311	.98535	.98677	1.07848
1973	.86878	.89858	.90772	.93728	.96094
1974	.82023	.80716	.85717	.90962	.79883
1975	.96159	1.08445	.93071	.90082	.86564
1976	.93084	.98996	.98711	.84402	.80782

11. PRINTING

YEAR	L	K	E	NR
1961	1.55838	1.16900	1.23117	2.21868
1962	1.43948	1.11993	1.18002	2.05579
1963	1.39801	1.12801	1.13424	2.09381
1964	1.30694	1.11846	1.08459	1.89986
1965	1.22763	1.05862	1.02055	1.96005
1966	1.17388	1.01894	1.07624	1.67059
1967	1.14433	1.00899	1.07287	1.49053
1968	1.12605	1.01192	1.13472	1.61404
1969	1.09181	.99828	1.11668	1.34072
1970	1.07632	1.02803	1.01197	1.07879
1971	1.00000	1.00000	1.00000	1.00000
1972	.92599	.95668	.99052	.81370
1973	.98944	1.01165	1.05529	.80485
1974	1.00526	1.04313	1.04010	.65795
1975	.90236	.97869	.87273	.57593
1976	.83019	.91901	.87905	.46808

12. PRIMARY

YEAR	L	K	E	NR
1961	1.25046	1.00287	1.11475	1.02189
1962	1.21260	.98519	1.05525	1.01428
1963	1.17563	.96611	1.02195	1.02104
1964	1.13848	.91326	1.06918	1.03745
1965	1.13920	.90333	1.05028	1.05361
1966	1.14417	.92891	1.00980	1.02609
1967	1.13956	.98918	1.04990	1.06664
1968	1.04359	.92975	1.00159	1.06460
1969	1.03341	.95835	.96920	1.07244
1970	1.02712	.95381	.98973	1.07073
1971	1.00000	1.00000	1.00000	1.00000
1972	.97468	1.00626	.96386	.98664
1973	.92643	.96686	.93768	.98528
1974	.93905	.97109	.94445	1.01369
1975	1.00155	1.15700	.97049	.95739
1976	.96378	1.20076	.85429	.97164

13. METAL FABRICATING

YEAR	L	K	E	NR
1961	1.45018	1.20272	1.25462	.96431
1962	1.38540	1.05937	1.12626	.95827
1963	1.33539	.99133	1.10834	1.00700
1964	1.25767	.89639	1.04043	.98181
1965	1.18864	.81878	1.01515	.99028
1966	1.16725	.82206	1.01127	.96669
1967	1.16272	.90746	1.00608	.94283
1968	1.10628	.92015	.98396	.96123
1969	1.07457	.92916	1.02261	.96056
1970	1.06744	.99453	1.02196	.97398
1971	1.00000	1.00000	1.00000	1.00000
1972	.94728	.96665	.98001	1.04490
1973	.87780	.88716	.89348	1.03777
1974	.80968	.80724	.87179	.99072
1975	.89326	.94195	.95818	.99481
1976	.88654	.95138	.96288	.99915

14. MACHINERY

YEAR	L	K	E	NR
1961	1.36944	1.01831	1.01792	.94659
1962	1.30387	.92520	.91120	.95205
1963	1.28517	.87852	.87385	1.03379
1964	1.15860	.78533	.81110	1.08034
1965	1.12091	.74151	.76464	1.07092
1966	1.06215	.71334	.77981	1.05226
1967	1.09511	.75779	.82145	.97700
1968	1.07838	.81035	.84601	.92714
1969	1.01632	.75935	.80499	.94618
1970	.98939	.79620	.78192	.85542
1971	1.00000	1.00000	1.00000	1.00000
1972	.99135	.94148	1.09593	1.06310
1973	.95023	.86964	1.03958	1.16119
1974	.86929	.78156	.97129	1.14567
1975	.92329	.86856	.92509	1.29318
1976	.94702	.96524	1.04637	1.24247

15. TRANSPORTATION

YEAR	L	K	E	R	NR
1961	2.07513	1.61824	1.60849	.54028	.99987
1962	1.89203	1.38161	1.36805	.52439	1.07883
1963	1.74092	1.20334	1.23047	.44584	1.08314
1964	1.70081	1.14532	1.15539	.46361	1.14331
1965	1.80394	1.03637	1.09364	.57885	1.09458
1966	1.45787	1.06145	1.12032	.60185	1.14151
1967	1.27928	1.02762	1.06895	.47047	1.00054
1968	1.18786	.98998	1.06827	.47752	.97081
1969	1.10789	.92090	1.00444	.60012	.97884
1970	1.19416	1.15668	1.12276	.86801	1.04842
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	.93558	.89423	.94376	.99222	1.04479
1973	.87726	.78137	.87158	.84039	1.01117
1974	.79698	.75166	.77791	1.09545	.84056
1975	.81592	.85741	.84491	.91298	.85356
1976	.79203	.82858	.81003	.66079	.79852

16. ELECTRICAL PRODUCTS

	L	K	E	NR
1961	1.56206	1.26346	1.42227	1.06565
1962	1.47566	1.13970	1.25420	1.02409
1963	1.39631	1.06565	1.24515	1.02194
1964	1.33612	1.00457	1.16808	1.05312
1965	1.27068	.93647	1.13869	1.09569
1966	1.24294	.89794	1.07974	1.08473
1967	1.22707	.96815	1.16162	1.03070
1968	1.12831	.97502	1.08970	1.00280
1969	1.05705	.93992	1.02873	1.02113
1970	1.02314	.98743	1.01268	1.00466
1971	1.00000	1.00000	1.00000	1.00000
1972	.90109	.95099	.90630	1.01217
1973	.84395	.88254	.86334	.97978
1974	.83744	.93475	.88459	1.01975
1975	.84511	.98803	.89423	1.03146
1976	.80332	.99603	.86447	.98671

17. NON METALLIC

	L	K	E	NR
1961	1.48486	1.03662	1.28035	1.10137
1962	1.36843	.92728	1.16118	1.04419
1963	1.33816	.92949	1.15403	1.07635
1964	1.27693	.87077	1.10311	1.11869
1965	1.23711	.84322	1.11210	1.13861
1966	1.19877	.88516	1.13651	1.08147
1967	1.24886	1.03861	1.13215	1.08452
1968	1.16135	1.00834	1.06722	1.12508
1969	1.12669	1.01038	1.04095	1.11612
1970	1.11196	1.11570	1.09642	1.09135
1971	1.00000	1.00000	1.00000	1.00000
1972	.96329	.94838	1.03594	.92357
1973	.90350	.90286	1.00344	.97730
1974	.89314	.90896	1.01416	.98288
1975	.91114	.98301	.95385	1.01288
1976	.89101	1.01988	.97447	1.04188

18. PETROLEUM

	L	K	E	NR
1961	1.61217	1.24422	.89633	.97939
1962	1.52746	1.17968	.82791	.93949
1963	1.31455	1.08064	.79080	.92258
1964	1.25075	1.04206	.88005	.91541
1965	1.16322	1.00571	.85581	.91688
1966	1.22852	.95782	.85498	.91736
1967	1.24785	.98115	.87300	.91765
1968	1.16011	.95439	.98122	.92659
1969	1.11800	.86587	1.04152	.96599
1970	1.09053	1.03196	1.02078	.97089
1971	1.00000	1.00000	1.00000	1.00000
1972	.91669	.99776	1.02064	1.00987
1973	.80874	.93078	.96670	.95501
1974	.56195	.65602	.67494	.63025
1975	.54587	.69822	.73101	.61662
1976	.54543	.77892	.78343	.63211

19. CHEMICALS

YEAR	L	K	E	R	NR
1961	1.56471	1.07348	1.34794	1.15226	.99497
1962	1.45300	1.03142	1.22635	1.21481	1.01436
1963	1.40175	.99700	1.21137	1.20961	1.01538
1964	1.31504	.94260	1.11052	1.11118	1.00363
1965	1.30738	.93643	1.07877	1.04930	1.00402
1966	1.17097	.94576	1.10946	.98028	1.04041
1967	1.16493	1.00776	1.11237	1.00589	1.01259
1968	1.13246	1.01862	1.08547	1.10363	1.08041
1969	1.06811	.98460	1.09306	1.01351	1.11883
1970	1.06679	1.01652	1.04599	.98555	1.02189
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	.91758	.97108	.91320	1.04600	1.09723
1973	.84019	.88281	.92092	.85050	1.07137
1974	.85027	.92935	.96254	.84791	1.09113
1975	.94324	1.15437	.93397	.93727	1.17286
1976	.90791	1.27948	1.07342	.86348	1.03325

20. MISCELLANEOUS

YEAR	L	K	E	R	NR
1961	1.26769	.73816	1.21105	.72930	.83569
1962	1.22529	.73771	.96957	.69148	.88921
1963	1.21529	.76654	1.02292	.73202	.92779
1964	1.16111	.74527	.97248	.67015	.85061
1965	1.11560	.74186	1.00225	.67192	.84084
1966	1.06378	.75434	1.06458	.51785	.79384
1967	1.00120	.79465	1.17021	.79847	.87010
1968	.91494	.78947	1.19003	.64632	.80605
1969	.87722	.76817	1.20878	.63860	.76689
1970	1.05499	1.03129	1.61485	1.05702	.96695
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	.95927	.95674	1.04852	.66318	.94651
1973	1.05778	1.02819	1.16202	.58198	1.10181
1974	1.21447	1.15878	1.16078	.71133	1.20660
1975	1.27500	1.23067	1.34050	.91228	1.10762
1976	1.21340	1.14411	1.07608	.56889	1.04108

21. TOTAL MANUFACTURING SECTOR

YEAR	L	K	E	R	NR
1961	1.40060	1.04063	1.18583	1.24442	.97241
1962	1.35020	.98942	1.13186	1.18969	.96379
1963	1.31126	.96573	1.09721	1.17853	.99813
1964	1.26280	.91936	1.08359	1.16101	1.00557
1965	1.22372	.89826	1.05659	1.07692	1.01365
1966	1.20485	.91279	1.04613	1.05827	1.00161
1967	1.18186	.95813	1.04569	1.06495	.98523
1968	1.11773	.95490	1.03818	1.02868	1.00630
1969	1.08267	.94296	1.03424	1.00239	.99800
1970	1.05887	.99903	1.03047	1.02427	1.01708
1971	1.00000	1.00000	1.00000	1.00000	1.00000
1972	.95884	.95997	.96270	.97012	.99443
1973	.90299	.89994	.90712	.89085	.98482
1974	.86170	.88540	.90658	.86538	.96363
1975	.89553	.99961	.87807	.88917	.96423
1976	.87894	1.01641	.89610	.94188	.93050

Appendix 4

Table 2: Aggregate Input Requirements, 1961-76

Food	Tobacco	Rubber	Leather	Textiles	Knitting
1.12091	1.14271	2.08109	1.34573	1.5934	1.87678
1.09188	1.1817	1.80174	1.30679	1.47225	1.84608
1.12603	1.10645	1.75465	1.23796	1.39326	1.74796
1.10831	1.18088	1.68461	1.17157	1.34341	1.61202
1.07135	1.05819	1.61077	1.17331	1.3511	1.51385
1.06092	1.01435	1.57959	1.18053	1.3459	1.38535
1.04815	1.04256	1.5665	1.14286	1.29914	1.37869
1.03933	1.11462	1.68084	1.09447	1.16577	1.21322
1.01908	1.03913	1.66009	1.07992	1.04573	1.16462
1.01738	1.06918	1.04352	1.0463	1.08754	1.12421
1	1	1	1	1	1
0.97797	0.9416	0.9525	0.95934	0.8983	0.9218
0.96752	0.92758	0.9137	0.99152	0.86765	0.89638
1.02238	0.91955	0.93498	0.97574	0.89602	0.92299
1.03513	0.91852	0.99959	0.9688	0.91225	0.85441
1.02509	0.90306	0.92793	0.90934	0.8785	0.81176

Clothing	Wood	Furniture	Paper	Printing	Primary
1.3619	1.13117	1.29354	1.02266	1.46866	1.07757
1.32048	1.09652	1.29936	1.02024	1.36816	1.05825
1.28205	1.06771	1.25825	1.00717	1.33946	1.04808
1.24581	1.03904	1.2339	0.99123	1.26861	1.04086
1.20669	1.02441	1.17138	0.99971	1.19446	1.04454
1.13425	1.01737	1.11569	1.00175	1.14387	1.03849
1.13084	1.01144	1.09843	1.05303	1.11802	1.07233
1.08403	0.98915	1.06797	1.04889	1.10565	1.03193
1.06561	1.00719	1.01761	0.99865	1.07476	1.03847
1.06476	1.00972	1.03188	1.00262	1.06638	1.03628
1	1	1	1	1	1
0.93522	1.01106	0.93336	0.96888	0.93218	0.98442
0.90385	1.00521	0.90413	0.89663	0.99369	0.96284
0.93821	1.01803	0.9987	0.83951	1.01095	0.98251
0.91944	1.00609	1.01962	0.96549	0.91361	0.99378
0.87749	0.94569	0.99032	0.93436	0.8439	0.98827

Petro. & Coal Prod.	Metal Fabric	Machinery	Transport	Elec. Prod.	Non-Met.
1.0736	1.22605	1.21574	1.72368	1.40144	1.26605
1.02603	1.17475	1.16002	1.58558	1.31978	1.16095
0.98213	1.16474	1.15737	1.45994	1.26178	1.15514
0.96737	1.10567	1.07369	1.43619	1.22407	1.11306
0.95631	1.06722	1.03959	1.44292	1.18585	1.09168
0.95607	1.04855	0.99592	1.29261	1.16017	1.0821
0.96131	1.04853	1.01172	1.15684	1.14753	1.15223
0.9574	1.02966	1.0037	1.09378	1.07992	1.10488
0.97098	1.01555	0.95802	1.03657	1.03451	1.08565
0.99302	1.02508	0.932	1.15276	1.01458	1.10851
1	1	1	1	1	1
0.99744	0.98332	0.9962	0.94861	0.93101	0.95921
0.93464	0.93376	0.97268	0.88293	0.87822	0.92199
0.62454	0.87145	0.90306	0.79759	0.88907	0.91989
0.61607	0.93533	0.97674	0.82929	0.90232	0.9458
0.63581	0.93465	0.99799	0.79573	0.86514	0.9505

Chemicals	Misc.	Total Manufacturing
1.30776	1.12027	1.20183
1.23364	1.0979	1.15925
1.19772	1.10423	1.14518
1.12638	1.04863	1.11595
1.11584	1.01705	1.08346
1.07122	0.97189	1.07357
1.09171	0.95758	1.07228
1.08389	0.88285	1.04541
1.04456	0.84799	1.02313
1.04404	1.04609	1.03234
1	1	1
0.9449	0.94882	0.96818
0.87622	1.04914	0.91647
0.90199	1.18962	0.88827
1.0153	1.21908	0.92116
1.04697	1.14405	0.91836

Appendix 4

Table 3: Nominal and Effective Rates of Protection

Table 3

NOMINAL AND EFFECTIVE RATES OF PROTECTION

(Percentages)

	NOMINAL RATES			EFFECTIVE RATES		
	1961	1966	1970	1961	1966	1970
1. Food	10.2	9.20	7.96	24.35	23.20	19.04
2. Tobacco	--	--	--	--	--	--
3. Rubber	18.42	16.72	14.36	26.66	24.67	13.17
4. Leather	20.70	20.20	19.23	34.09	35.66	33.78
5. Textiles	20.33	18.55	17.00	28.89	26.07	23.67
6. Knitting	27.72	26.75	23.08	38.31	38.95	33.73
7. Clothing	24.05	23.42	21.46	28.29	27.13	25.90
8. Wood	6.44	6.06	4.59	14.44	12.54	9.36
9. Furniture	20.47	19.33	15.59	26.97	25.61	20.19
10. Paper	10.76	7.06	6.09	16.29	10.69	9.33
11. Printing	6.91	7.83	6.89	5.39	7.93	8.17
12. Primary	6.36	4.21	2.86	13.97	10.01	6.91
13. Metal Fab.	14.76	13.49	11.27	20.91	18.80	15.57
14. Machinery	7.55	6.95	5.36	7.67	6.17	4.29
15. Transport	8.07	3.74	3.06	9.08	2.42	2.22
16. Electrical Products	15.19	15.33	12.43	19.54	20.44	16.54
17. Non-metallic	12.49	8.20	6.24	19.53	12.59	9.47
18. Petroleum & Coal Products	6.25	7.70	7.90	27.61	48.37	44.41
19. Chemicals	10.27	9.43	8.34	15.23	15.52	10.43
20. Miscellaneous	12.72	11.17	10.76	17.24	15.27	14.50

Source: B.W. Wilkinson and K. Norrie, "Effective Protection and the Return to Capital" Economic Council of Canada, 1975

Appendix 4

Table 4: Estimated Coefficients Assuming Factor Augmenting Technical Change, Total Manufacturing

APPENDIX 4

Table 4

Estimated Coefficients Assuming Factor Augmenting Techinical Change

Total Manufacturing

AL	.26219 (1.086)	DLQ	.01890 (.768)
AK	1.06935 (8.648)	DKQ	-.08978 (-7.027)
AE	-.01771 (.389)	DEQ	.00589 (.251)
AR	.64055 (3.596)	DRQ	-.04674 (-2.583)
ANR	-.95309 (-4.890)	DNRQ	.11161 (5.696)
BLL	.16588 (7.498)	ELt	-.03252 (-4.456)
BLK	-.01668 (-1.227	EKt	.03797 (5.656)
BLE	-.0000079 (-.0016	EEt	-.01401 (-1.331)
BLR	-.06446 (-4.526)	ERt	-.00198 (-.268)
BLNR	-.08473 (-7.864)	ENRt	-.02049 (-2.763)
BKK	.09418 (9.204)	α_0	5.75529 (31.240)
BKE	-.01278 (-3.855)	α_Q	.00060 (.026)
BKR	-.02820 (-3.202)	BQQ	.08633 (53.881)
BKNR	-.03650 (-5.962)	R^2(L)	.9270
		DW	1.4407
BEE	.02620 (10.625)	R^2(K)	.9893
		DW	1.8827
BER	-.00969 (-2.927)	R^2(E)	.9433
		DW	2.6104
BENR	-.00385 (1.523)	K^2(R)	.8956
		DW	2.1188
BRR	.13921 (9.280)	R^2(NR)	.9846
		DW	1.5461
BRNR	.03679 (3.961)		
BNNR	.16187 (17.531)		